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ON THE NATIONAL IMPORTANCE

OF

STUDYING ABSTRACT SCIENCE

WITH A VIEW TO THE

HEALTHY PROGRESS OF INDUSTRY.

(BEING AN INTRODUCTORY LECTURE TO THE COURSE OF CHEMISTRY, SESSION 1851—1852.)

BY

LYON PLAYFAIR, C.B., F.R.S.

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THE raw material used by Industry for the production of useful objects doubtless forms the basis of manufactures, but possesses a fluctuating value in relation to that of the object into which it is converted. In the successful prosecution of manufactures, apart from the influence of mere capital and labour, two elements are involved, each forming a factor which in a competition of industry may be made to assume very different values. The first element is the raw material; the second, the skill and knowledge used in adapting it to the purposes for which it is designed. Thus, in America, cotton is indigenous, and consequently cheap; and fuel, the other raw material employed in its conversion to a textile fabric, is not expensive. In England, the same cotton is much dearer, but the fuel may be assumed to be equal in price. The competition between the two countries in respect to calico resolves itself into the necessity that England, to overcome the disadvantage of the greater cost of the raw material, must infuse a greater amount of skill and knowledge into the processes employed in its adaptation to useful purposes. England has succeeded in doing this; and, consequently, the mills of Manchester may render unproductive the

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Note.—Some years since, I gave a lecture, never published, though a few copies were printed for private circulation among my students, the subject being similar to this. A demand having been made for it by publishers, as expressive of a want now acknowledged by manufacturers to exist, I have preferred taking this opportunity to write a new lecture on the same text, incorporating some of the passages of the former lecture.

mills of Lowell. But reverse the conditions of the two countries, and a similar result attests the truth of the same principle. Sheffield produces steel, which is exported in large quantity as a raw material to America. The history of that country has created a knowledge of the conditions required for the manufacture of edge-tools. The forests were not cleared, or the prairies converted into arable land, without that observing nation understanding the qualities and the requirements of the axe, the adze, and the spade. The knowledge thus attained was applied to the manufacture of edge-tools; and America returns to England its own steel, but under a new form, and endowed with an excellence, a temper, and a cheapness yet unattained by our artisans. Without this application of greater skill it would have been impossible for America to have competed with the country producing the raw material.

A nation, if it combine ordinary intelligence with its local advantages of cheap raw material, may long preserve almost a monopoly in special manufactures, and will continue to do so, either until the competing nation has risen so high above her in intelligence as to make this more than an equivalent for the local advantage of the other, or until a greater equalization in the price of the raw material renders a small amount of superiority in the intellectual element of sufficient importance to secure successful competition.

But should any great transition of the world take place, and should means arise by which local advantages were levelled, and the raw material confined to one country became readily attainable by all, the difference in its cost being inconsiderable, then the competition in industry must become a competition in intellect; and the nation most quickly promoting the intellectual development of its artisans must, by an inevitable law of nature, advance; whilst the country neglecting its industrial training must as inevitably recede.

It requires no mental acumen to perceive that we are rapidly approaching to, if we have not yet arrived at, this period of wonderful transition, when nations must speedily acquire the levels due to their different amounts of intellectual development.

It is quite true that a superabundance of capital may for a time preserve a country from a quick depression, even should it lapse in its intellectual training; but the support thus given can only be temporary and illusory, for if, by the purchase of foreign talent, the necessary knowledge is infused into home manufactures, this can only have the effect of raising the intellectual element in the foreign country, and thus finally accelerate its success as a competing nation.

There never was a time when it was so necessary as now that skill and science should be united for the promotion of the industrial arts. At former periods of human history, local advantages or accidental combinations were the foundations of a nation's prosperity. The time is not distant when it was thought that the possession of mineral fuel indicated a country as the natural manufactory of the necessaries of life employing machinery for their production; while the existence of large tracts of land, warmed by a genial sun, stamped another nation as essentially agricultural, and employed its population in the labours of the field. Each country fell into a routine of manufacture; and Italy and France produced their silks and shawls, with as little thought of competition as England its machinery and calicoes.

Science in advancing has created resources unthought of before, and has removed the local barriers opposed to the progress of industry. Countries were no longer confined in their aspirations by smallness of territory, for this by the aid of science enlarged its powers. The country able in its agricultural poverty to support only a scanty and miserable population, expanded itself for the reception of increased numbers as the produce of its land augmented, and thus knowledge, in the improvement of agriculture, won by a bloodless victory vast additional territory to aid in the industrial resources of the nation; for a land, with a twofold increase in agricultural production, has, for all practical purposes, unfolded itself to twice its size. Science in its progress was improving and simplifying processes of manufacture, while it was opening at the same time a communication between the nations of the earth. The amazing facilities of transport afforded by the introduction of steam

enabled a ready interchange of their natural riches; and mere adventitious local advantages, apart from skill and science in their adaptation, became of much less moment than they formerly were. The proof of this is in the fact, that the staple manufactures are now carried on in all parts of Europe, and that there is a constantly increasing and active competition of most of the great nations in all the markets of the world. If England still continue in advance, it will not be from the abundance of her coal and iron, but because, uniting science with practice, she enables her discoveries in philosophy to keep pace with her aptitude in applying them.

But is it true that England does act thus wisely; and is it true that science does hold in this country its just position in public esteem, or that it is fostered sufficiently to make that progress which it is now doing in other lands? To all such questions a negative reply must be given; for beyond a theoretical recognition of the importance of science in its relations to practice, and the establishment of this museum and college—a very important measure, I admit—the state and the public only look to the empirical result, and have not deemed it necessary to foster the knowledge producing it. But England is the only European state thus blind to its own interests, and not yet thoroughly awakened to the importance of giving an intellectual training to those intrusted with its manufactures. This is proved by the large endowments given by foreign governments for the support of institutions connected with industrial science, and it finds expression in the writings of their thinking men. "An equal appreciation of all parts of knowledge," says Humboldt, "is an especial requirement of the present epoch, in which the material wealth and the increasing prosperity of nations are in a great measure based on a more enlightened employment of natural products and forces. The most superficial glance at the present condition of European states shows, that those which linger in the race cannot hope to escape the partial diminution and perhaps the final annihilation of their resources. It is with nations as with nature, which, according to a happy expression of Goethe, knows no pause in ever-increasing movement, development, and production—a curse still cleaving to standing still.

"Nothing but serious occupation with chemistry and natural and physical science can defend a state from the consequences of competition. Man can produce no effect upon nature, or appropriate her powers, unless he is conversant with her laws, and with their relations to material objects according to measure and numbers. And in this lies the power of popular intelligence, which rises or falls as it encourages or neglects this study. Science and information are the joy and justification of mankind. They form the springs of a nation's wealth, being often indeed substitutes for those material riches which nature has in many cases distributed with so partial a hand. Those nations which remain behind in manufacturing activity, by neglecting the practical applications of the mechanical arts and of industrial chemistry, to the transmission, growth, or manufacture of raw materials—those nations among whom respect for such activity does not pervade all classes—must inevitably fall from any prosperity they may have attained; and this by so much the more certainly and speedily as neighbouring states, instinct with the power of youthful renovation, in which science and the arts of industry co-operate or lend each other mutual assistance, are seen pressing forward in the race."

It is but the overflowings of science that thus enter into and animate industry. In its study we are never sure that the morrow may not gladden the world with an application of a principle to-day abstract, and apparently remote from practice. This is a truth above all things necessary to convert into a living faith in the minds of those who devote their lives to its practical applications. Nothing is more erroneous in their case than to neglect the acquisition of abstract scientific truths because they appear remote from practice. I do not admit that it is even wise to address to oneself the question *cui bono?* Science is too lofty for measurement by the yard of utility;—too inestimable for expression by a money standard. These groveling ideas of the objects of science, which constantly jar it in its intercourse with the world, ought to find no response in the breast of any devotee who would draw inspiration from its shrine. But whilst I protest against the indulgence of a mere utilitarian appetite for science, I think it infinitely advan-

tageous to examine it in its practical relations to life; but it must not be forgotten, that though the object of industrial study is to view science in its beneficent overflowings of kindness to man, these material benefits arise from the very fullness of its measure. If we revert back to the intellectual wanderings of science in its search for truth, it becomes surprising how soon it shook off the trammels of ignorance, and developed into a glorious liberty. Let us recollect how much science has advanced within the last three centuries, and even her past history becomes more remarkable in its progress than the present. It is no mean task for intellect to leap over the barriers of ignorance; it is even more easy to go onward in new and untrodden paths. It was only at the end of the sixteenth century that the Council of Sages at Salamanca negatived the idea of a western continent, by the writings of Lactantius. "Is there any one so foolish," says he, "as to believe that there are antipodes with their feet opposite to ours; people who walk with their heels upwards and their heads hanging down? That there is a part of the world in which all things are topsy-turvy; where the trees grow with their branches downwards, and where it rains, hails, and snows upwards?" Do we not know that Columbus was told by the Sages, that were he to succeed in sailing down the rotundity of the earth its bulging out would prevent him ever sailing up again; and do we not remember with what a stedfast faith in abstract truth he saw beyond "the region of the torrid zone, scorched by a blazing sun, a region of fire, where the very waves which beat upon the shores boiled under the intolerable fervour of the heavens?" Recollect that these were the opinions of a time when the utmost national encouragement was given to intellectual progress, and that it was not very many years after the death of Prince Henry of Portugal, who gave that glorious motto to princes, "the talent to do good." Recollect that this ignorance was manifested in the brightest time of the reign of the enlightened Isabella of Castile, and you will be surprised with me that science has since that time achieved what it has. Had Columbus not investigated the abstract truths of cosmography, the western continent, even with the advantage of the "astrolabe," discovered in his time, would perhaps for a century have re-

mained unknown. It is easy to make an egg stand on its end when the way is shown how to do it. The applications of science are not difficult, but without the science there are no applications. The philosophy of our times does not expend itself in furious discussions on mere scholastic trivialities, or unmeaning questions in theology. The scholastic learning of the middle ages was much confined to ecclesiastics, and it is not surprising to find both classical and theological literature engrafting itself upon the science of the time, and forcing it into the discussion of questions very foreign to its nature. It was a curious mixture of theology and science when the most learned men agitated themselves on subjects such as—the manner in which angels are nourished?—whether they usually speak Hebrew or Greek?—what are the spirits entrusted with the distribution of lightning and hail, and to which are confided the digestive powers of animals?—whether Adam, before the Fall, was acquainted with the *Liber Sententiarum* of Petrus Lombardus? The polemics of a past age do not represent the search after abstract truth of the present. Yet you are in no position even now to treat with derision the past errors of philosophy. The man who is on the mountain complains of the fog obstructing his view, while the inhabitant of the plain speaks of it as a cloud capping the mountain. Both are right, but read the phenomenon differently from each other. Yet only he that was in the fog could rightly appreciate its darkness, or fully understand the force of the rising sun that dissipated its obscurity. The progress of knowledge,—the search after truth,—can scarcely be recognized in its sublimity by those who do not understand the errors which had to be swept away before it could advance in an uninterrupted path.

There are very few instances in the history of science of a sudden development of great discoveries, either illumined from darkness by a flood of light from genius, or betrayed through some accidental and straggling ray. The growth of scientific discovery is slow, and does not, like the prophet's gourd, spring into full development in a single night. The great discoveries of science leave behind them no boundary line of demarcation from those which have preceded, but, like the full day succeeding

the dawning of the sun, follow that which fully foretold their approach. The telescope and microscope did not open their wonders to an unexpecting and startled world, but crept into existence with steps so slow that their impression is not sufficient to trace out the history of their progress. The improvements in the steam-engine were so gradual that a court of law, only half a century since, gave a solemn judgment that Watt had done nothing essential towards them. The compass cannot point to us the period when it offered its inestimable services to man, nor has paper left a record of its discoverer. In fact, all great practical discoveries are the result of much study, the exponent of a long series of observations, and often arise out of those truths of science which appeared least promising on their first announcement. Boyle knew that he wrote an imperishable truth when he titled his Essay "Man's great ignorance of the uses of Natural Things; or, that there is no one thing in Nature whereof the uses to Human Life are yet thoroughly understood." This truth of the seventeenth century is no less true in the nineteenth, the history of the intermediate time having been, as Sir John Herschel justly remarks, but one commentary on the text. The everyday progress of the arts abounds in new applications of objects the most familiar.

Practical, like abstract science, has no limits. The Romans thought themselves at the culminating point of civilization; and the Greeks, pluming themselves in their inventiveness, could not conceive that the world would ever take a higher flight. Even in our times, like opinions are entertained; because ignorance cannot see over the heights raised by modern science for a wider view of creation. These conceited ideas of a nation or of an age have no foundation. Science may see an horizon bounding her view; but as she proceeds onward the horizon constantly recedes, and shows the limit to be altogether illusory. In one time and generation a nation may, like Newton, pick up a few pebbles on the seashore, while the boundless ocean of science lies beyond, with all its vast and unexplored treasures.

Empiricism has frequently been a substitute for science; a lame and sluggish substitute, it is true, but nevertheless one

that in the history of mind has had much of influence. Gunpowder was known before the condensed air of which it consists was recognised or understood; and it succeeded in killing man, without a knowledge that man himself is little more than air similarly condensed. Man used and succeeded in producing condensed air in the form of food, without having the slightest conception of the character of the air out of which this wondrous transformation was effected. Without a knowledge of atmospheric pressure, mills and pumps were formed. Glass was produced from the ashes of the fern, and china from kaolin, without a knowledge of the principles involved in their production. The length of the year was known, and the duration of the seasons explained, without the law of gravitation being suspected. All this, it is true, arose without science, but required ages to grow into a stunted and feeble childhood; while no sooner did science remove the trammels of ignorance, than a few short years produced a vigorous manhood. Ignorance may grope in darkness on the confines of an unexplored region, but to proceed steadily and securely onwards she must borrow the lamp of science to guide her. Newton, "that glory to his species," as Chalmers calls him, did, by the exposition of the law of gravitation, produce more real practical benefits to industry than all the preceding ages of empiricism. Navigation and Commerce sprang from his time into a state of development formerly impossible; and every nation and every human being enjoys from him, and to the end of time will enjoy, actual material benefits which an eternity of empiricism could not have produced. The hard-won experience of two thousand years of the Chinese in regard to porcelain was given to the European by a few years applications of science. The improvements in postal communication, which allowed our kings to transmit a message to Edinburgh in five days, now enable us to send it in less time than their "post-haste messenger" could saddle his horse. But these, and other triumphs of mind over mere empirical experience, arose from a steady progress of abstract science, the practical applications appearing merely as offshoots. It is my chief object to show that abstract science is necessary to the development of

practice, and that it is above all things necessary to make it a part of the education of a man who is to devote his life to the progress of industry. There is no vein of science too abstract for future industrial application; none yet thoroughly mined out and exhausted. Volumes might be filled with illustrations of the practical benefits produced by the application of discoveries apparently the most unpromising in their origin; but a few only can be selected in support of the text of my argument.

The most "practical" man,—a title erroneously used by our English to envelope their ignorance,—could not have objected to the marvellous development of truth arising from the study of light, that messenger from the sun travelling to us at the rate of 180,000 miles in a second, to illumine our earth with the glory of its parent. It was wondrous to be told that the light of yonder far-distant fixed star, travelling without cessation at the same incredible speed, and which has this night struck our wondering eyes, started in its long and weary course some billions of years since, and has now for the first time shed its pale light on such points in time and space as ourselves. The sublimity of these truths awes the utilitarian, and hushes his half-uttered question of *cui bono?* But show him a young officer of artillery looking through a prism at the windows of the palace of the Luxembourg, and noticing that, in a particular position, the light of these windows disappeared from his view—show him, further, the startled wonder with which the philosophers of Europe heard of this phenomenon, and the eagerness with which they threw themselves into the track of an observation apparently so insignificant,—and your utilitarian sneers at science and its followers, and buries himself again in the darkness of his empiricism. The light reflected from the palace of the Luxembourg had suffered a change similar to that experienced by ordinary light in passing through doubly refracting Iceland spar. When a ray of this changed or *polarized* light is passed through plates of crystallized substances, brilliant colours and a peculiar structure are observed. These remarkable phenomena were indeed well worthy of the attention of scientific observers. Nothing, however, could

appear more remote from practice than the study of an altered beam of light. It was most interesting that, as in the case of sound, where two sounds reaching the ear either exalt or destroy the effect, so, in light, two rays interfering with each other may produce darkness. Much of the light from reflecting surfaces was found to possess this changed condition. The light coming from the surface of water being thus altered, refuses to pass through a "Nicolls' prism" in a particular direction. If, therefore, you look at the shadow of a man on a smooth lake, on turning round the prism the shadow disappears, while the man, seen by common light, remains visible. The story of Peter Schlimmel is thus realised. But who, from these curious observations, would have dreamt that out of them would come useful applications?

In a short time, however, this property of the polarizing prism was applied to the important purpose of detecting rocks and shoals at sea. It had long been the practice of mariners, when they suspected the existence of shoals, to look out for them at the masthead, because the outlook from his vertical position shut out much of the light that dazzled and obstructed his view. But as part of this dazzling reflected light is polarized, it is obvious that the polarizing prism enables the observer to scan the depths of the ocean, uninterrupted by its glare. Behold then the light which struck the student's eye when gazing on the Luxembourg used to preserve man from the hazards of the sea. It was easy to apply it in new directions; and the salmon-fisher speared fish at depths inaccessible to his unaided vision; while the engineer used its searching powers to discover the laws of tension in beams. Mechanics and chemistry both pressed it to further their resources. Under the hands of a Biot, a ray of polarized light performed with magical quickness the most refined but tedious operations of the analytical chemist, and enabled him to tell the amount of sugar in the cane or beet juice. He thus followed the increasing richness of sugar in the juices of various plants at different stages of their growth, and was enabled to suggest a more economical adaptation of the labour applied to their cultivation. Thus, when beet is ready to be gathered, labour is in demand for the harvesting of other

crops, and consequently is expensive. It would not then do to take another crop, such as parsnips, inferior in its amount of sugar, as the cost of production would outweigh the return; but when the horses and carts are disengaged, and labour is cheap, parsnips are richest in their amount of sugar, and the idle mills may be usefully employed in producing sugar from this plant. By the same ray of light the size of distant objects may be measured, and even time may record its passage. This latter application, made by Wheatstone, is especially remarkable, and gives a means more accurate and useful than the sun-dial of determining the apparent solar time by the diurnal changes of the plane of polarization at the north pole of the sky. By availing himself of the fact, that the planes of polarization in the north pole of the sky change exactly as the position of the hour circle alters, he has adapted a simple and ingenious apparatus, by which the true time may be told within three minutes. All these are strange paths to practice, opened out by a ray accidentally caught in its passage from a window of the Luxembourg. Pass from its utilitarianism to its unfolding of nature's laws, and follow the same straggling ray, as it silently displays its gorgeous colours while passing through a transparent mineral substance, until it gives to man the knowledge as to whether the light of the sun proceeds from its solid mass or from its gaseous canopy, or whether comets enjoy light of their own, or borrow it by reflection from other bodies.

I now pass to light in its ordinary form, and ask you to examine the importance of studying its abstract phenomena. The world had long known that salts of silver were blackened by exposure to light; and the fact became familiar by their use as cauteries, or as indelible inks for linen. Wedgwood proposed to apply this means to fix the fleeting pictures of the camera obscura; but the results of his experiments being imperfect, the suggestion itself was almost forgotten. In the meantime chemists pursued their abstract discoveries, and without relation to this want investigated the properties of gallic acid, and of the iodide of bromine, and found a class of salts termed the hyposulphites. Some of these bodies pos-

sessed properties accelerating the blackening of silver salts by light; the others prevent the further blackening when applied. Philosophers began now to revert to the old idea, for truth is never lost, though its reality may be incapable of proof at a given time; and thus various unconnected discoveries began to react one upon the other, until man was able to use the sun as the painter of the pictures exhibited and enlivened by her glory. So perfect became the art, by new adaptations of other discoveries, that the most fleeting objects can be depicted. The flash of lightning exhibits its fiery streak on these sun-painted pictures. The tossing out of lavas, the vomiting forth of smoke, and the bellowing of flame from craters in their wildest moods, are pourtrayed with unerring fidelity; the tumultuous dashing of the cataract and the slight rippling of the stream, the changing forms of the clouds, the sparkling of the rain-drop, and the ever-varying expresssion of the human countenance, are all capable of being preserved in these paintings by nature. Nay the truthfulness of the sun-painted landscape is so great that from the very shadows of the picture the altitude of the sun may be determined; and the time at which it was taken being known, the latitude of the locality may be elicited. Artists now use this application of light to acquire models for study; and the engineer employs it to obtain proofs of the exact state and progress of the works superintended by him. Doubtless very soon, for it is now all but accomplished, the sun will be compelled to fix those transitory coloured glories which she now imparts to natural objects; but not till then should man cease to question her as to the means of accomplishing this end. I need not say that this art is but disclosing its future applications. Already can we use the sun to record observations too delicate for man's perception. The constant and momentary excursions of the magnet, the ever-recurring variations of the thermometer and barometer, are now recorded by light with a fidelity and precision unattainable by the most conscientious and unremitting observers.

These instances will suffice to show that the study of abstract laws, so far as regards light, produces as offshoots important practical applications; and in each department of science, like

lessons may be taught. There never was an age so rich in practical applications as that in which we live, and it is interesting to see them drawn from truths long familiar to man, and apparently beyond the range of utilitarian application. When an Italian physician, having hung on an iron railing the legs of a frog fastened to copper hooks, observed that each gust of wind caused convulsions in the legs of the dead animal, who could have prophesied that this accidental observation would entirely alter the character of a future century; and yet it is but an application of this discovery, extended, it is true, by many intermediate researches, that annihilates space and time,—that empowers our thought to travel with the speed and with the power of lightning to the most distant land, and enables mind to be reciprocated without being arrested by distance in space. Who could have dreamt that the same discovery of Galvani would in future join continents, in spite of intervening seas, and give more security to nations than cordons of soldiers or fleets at sea, by rendering sudden invasion all but impossible. At the late Exhibition you had a singular proof of this quick interchange of intelligence, for every morning you could buy at a trifling cost a map showing the state of the wind, of the barometer and thermometer, in all the principal towns in Great Britain during the previous day. You have already seen how useful may be made this discovery; for a transit of a star at Greenwich and at Paris may be instantaneously recorded, and their respective longitudes verified. As a means of communicating intelligence, its powers are not yet nearly developed; for in its mercantile communications it produces results no less individually important than in its general results, such as when it sends information to distant provinces of the approach of a tornado, time being thus given to provide against the fury of the storm. It is rare indeed that brilliant discoveries, such as the electric telegraph, flash matured across a human intellect, and in a generation produce such mighty results. It is true that some of the most wonderful discoveries have been shadowed forth by a sudden inspiration; but in few cases has that shadow appeared as a picture with all its lights and shades. Before steam had been subjugated to the service

of man, in accelerating his transit on land or water, Darwin had said,

> " Soon shall thine arm, unconquered steam, afar
> Drag the slow barge, or move the rapid car."

It was a similar inspiration that showed to Goethe that the parts of flowers are metamorphosed leaves, and that made Oken, when stumbling over a bleached skull, perceive that the osseous system was constructed on the vertebral type. But it was only by patient and long-continued study that these thoughts became substantive realities. This is essentially the case in electricity, which is but now beginning to reward mankind at large for all the patient investigations of the philosopher. Already has the fierce and untamed lightning allowed itself to be dragged from its course, and be conducted tranquilly to places where its fury is dissipated without injury to man. Even in its fiery flashings in the wide expanse of the ocean, it submits to the intellect of a Franklin, and leaves unscathed the ship rolling on the stormy waves. Providence, in His beneficence to man, has allowed him to find " a way for the lightning of thunder." Artificially formed, it allows itself to be conducted through land and sea, humbly serving the purposes of man, by blowing up mines, or enabling him to rescue treasures from sunken vessels.

This immaterial power produces material results at places fixed on by the will of man; and London may now fire a friendly salute at the Invalides, while Paris returns the compliment with the guns of the Tower. Although, as yet, electricity is not used with economy as a motive power, the obstacle is only in the cost; and even this may be resolved as discoveries progress.

Although her passage is so rapid that a journey to Paris can scarcely be expressed in time, yet she may be controlled, and used to record time's own progress; for nothing is more accurate than clocks worked by her power. It would not be difficult to have all the clocks in a town worked with perfect uniformity by the aid of electricity.

Electricity now plates with gold and silver the baser metals; copies in metal from more perishable materials the most exquisite designs and forms; perpetuates the skill of the engraver, by

multiplying, at a trifling cost, his elaborately engraved plates; and separates and purifies the metals, formerly only obtainable by tedious and complex chemical operations.

Electricity offers for your lighthouses light of a brilliancy the most intense, and asks you to substitute the light gas which streams through the streets by a still more ethereal existence, running along simple wires.

Even in the smallest offices of good-will to man she refuses not her aid, and offers to tell the perfumer whether his essential oils are adulterated with cheaper fatty substances, as willingly as she lends aid to the chemist in the minute operations of his laboratory practice, or as she kindly ministers with the physician to allay human suffering and restore wasted strength. Recollect, that all these are but the beginning of her applications, and that we know not to what extent they may be carried out; and rejoice with me that philosophers studied her abstract laws, from the knowledge of which these applications have arisen.

I have no time to extract further examples from physics or meteorology, but I cannot refrain from directing a passing glance at the beautiful discoveries of Colonel Sir William Reid. Studying the phenomena of a hurricane at Barbadoes, he followed out his observations to all recorded hurricanes, and thus elicited the simple law that hurricanes and many gales are progressive whirlwinds, revolving in the direction of the hands of a watch in the southern, and in the reverse direction in the northern hemisphere, but moving along in its mass at the same time. The variable winds in a hurricane now become intelligible, and a mariner caught by it may use every wind to steer out of its course, and prevent himself being overwhelmed in its vortex. To be wrecked in a hurricane, with an open sea, can now only result from a lamentable ignorance of scientific laws; for knowledge has triumphed over the terrors of the storm.

Let us now turn to chemistry proper, and see how this supports the text of the argument. It is an old science, and from the time of Tubal Cain to that of Liebig has been progressing steadily onwards, though not always with similar aims and aspirations. The alchemists erred, as England now errs, by valuing and studying only practical applications, instead of following

abstract laws. Health, wealth, and longevity comprised their aspirations, in the place of eternal truth. But these objects were sufficiently important to produce in their search "a zeal allied to madness," and facts became accumulated of infinite importance to the science when it attained self-consciousness, and learned to value itself for its nobler ends.

No later than the time of Henry IV., a royal edict recommended that "the clergy should search for the philosopher's stone, for since they can change bread and wine into the body and blood of Christ, they must also, by the help of God, succeed in transmuting the baser metals into gold."

As soon as chemistry began to be studied for the mere sake of abstract truth, then she deigned to reward man for his unselfishness by numerous collateral results having a direct material benefit.

"The philosopher's stone," says Liebig, "for which the ancients sought with a dim and ill-defined impulse, was, in its perfection, nothing else than the science of chemistry. Is not that the philosopher's stone which promises to increase the fertility of our fields, and to ensure the prosperity of additional millions of mankind? Does not chemistry promise, that instead of seven grains we shall be able to raise eight or more on the same soil? Is that science not the philosopher's stone which changes the ingredients of the crust of the earth into useful products, to be further transformed by commerce into gold? Is that knowledge not the philosopher's stone which promises to disclose to us the laws of life, and which must finally yield to us the means of curing diseases and of prolonging life?"

He who supposes that chemistry is the result of practical knowledge derived in its contact with industry knows little of the progress of the human mind, or is little grateful for the infinite development which it has given to human resources and human enjoyment. Let us select a few examples of abstract chemical truths bearing on practical appliances. I will first refer to the Miners Safety Lamp as a most important example of an industrial result depending upon pure induction from abstract science. An element of destruction, apparently uncontrollable by human power, had to be subjugated so completely as to be put under the management of the most uneducated

miner. More dreadful in its effects than those of the lightning and the earthquake, fire damp, the scourge of the miner, seemed to defy investigation even as a scientific phenomenon. By a pure inductive method, such as a Bacon would have loved to witness, Davy traced its history, step by step, until he fully made out all its characters. He discovered that it in reality requires a very high heat for ignition, the temperature of red-hot iron or charcoal being insufficient to inflame it. The gas was found not to explode in narrow tubes, as these cool it below the point of ignition; and a network of iron wire is only a series of sectional tubes. A lamp surrounded by wire gauze is now constructed, and this allows a light to be carried into the most dangerous mine with perfect safety. What a wonderful discovery is this! The destructive gnome of the mine is imprisoned within a cage of mere wire gauze, and, vainly struggling to escape, heats to redness the bars of its prison. Science, to its glory, has destroyed those scenes of death and heart-sickening misery which haunted the miner in his most peaceful hours, and has rendered safe an occupation formerly one of dread and danger.

When Dumas investigated the laws of substitution, and discovered a new body by distilling alcohol with bleaching powder, interesting indeed in its chemical formula, but capable of being sneered at by those who see science at a distance, by a wrong-end telescopic view of its commercial productiveness; who could have dreamt that this *chloroform* was destined to remove many of the woes which man is heir to, by mitigating pain, and preventing its occurrence even in the most severe surgical operations?

In 1842, I had the pleasure of travelling with the Dean of Westminster and Liebig over different parts of England. Among other places we visited a limestone in the neighbourhood of Clifton, where in former times saurian reptiles had been the pirates of the sea. There, along with the relics of the fishes on which they had preyed, were their own animal remains. Coprolites existed in great abundance, and proved the extraordinary number of the reptiles which must have existed. The interesting question arose as to whether these excretions of extinct animals contained the mineral ingredients of so much value in

animal manure. The question was in fact not yet solved by the chemist, and we took specimens, in order to confirm by chemical analysis the views of the geologist. After Liebig had completed their analysis, he saw that they might be made applicable to practical purposes. "What a curious and interesting subject for contemplation! In the remains of an extinct *animal* world England is to find the means of increasing her wealth in agricultural produce, as she has already found the great support of her manufacturing industry in fossil fuel—the preserved matter of primeval forests—the remains of a vegetable world! May this expectation be realised! and may her excellent population be thus redeemed from poverty and misery!" I well recollect the storm of ridicule raised by these expressions of the German philosopher, and yet truth has triumphed over scepticism, and thousands of tons of these or similar animal remains are now used in promoting the fertility of our fields. The geological observer, in his search after evidences of ancient life, aided by the chemist, excavated extinct remains which produced new life to future generations.

Two years before this, the same German philosopher, in his researches into the food of plants, had drawn attention to the importance of guano as a manure, and by his intellect wafted fleets to the Ichaboes and to the Incas.

Man gets so accustomed to luxurious applications of science, that he often forgets the searcher of abstract truth whose discoveries led to them. Nothing is more useful than has been the discovery of the lucifer match. Some of us recollect the time when the tinder-box was the only artificial means of procuring light, and a lively remembrance of the often-unsuccessful efforts, always tedious and lengthy, is required fully to appreciate the value of the lucifer match. What an improvement it was when a little bottle of oil of vitriol could be carried about, and by dipping matches into this, light was obtained! And yet this elegant method is now considered clumsy, and is entirely superseded in less than ten years. The properties of chlorate of potash and of phosphorus became by study better understood, and their application to the production of artificial light was apparently perfected. But the lucifer

match maker is dangerous to society, and a curse to himself. The transparent waxy phosphorus with which he works must always be kept under water, and even then is so hazardous that insurance offices decline to insure the premises in which it is contained. The heat of the hand causes it to inflame, and the worker, even avoiding this, becomes diseased and liable to ulcers. The practical man now helplessly lays his wants before the searcher of abstract truth. Chemists had for some time noticed that various bodies assume different forms, as, for example, carbon, in the states of diamond, graphite, and charcoal. An Austrian chemist, Professor Schrötter, investigating the abstract laws of allatropism, inquires whether phosphorus has more than one form, and by heat changes the transparent wax into a scarlet body. This scarlet substance is the same phosphorus, but in a state in which it may be kept in the open air, or packed up and transported in casks, and is not readily inflamed by a gentle heat or by friction. Physiologically it has little action on the body, and yet by proper admixtures makes as good lucifer matches as the ordinary dangerous phosphorus. By these discoveries the means of giving artificial light is rendered a safe and healthy manufacture.

A French chemist discovers that paper immersed in nitric acid unites with that body, and becomes highly combustible. Any woody fibre is subsequently found to do the same. This observation lies dormant for years, noticed only as an interesting fact, under a long and scientific term, in the books of chemists. But one day a Swiss chemist announces the startling fact, that the peaceful cotton bales of Manchester may be converted into dangerous ammunition of war, and that cotton unchanged in its physical appearance has been made more destructive than gunpowder. There was something appalling in the fact of this peaceful representative of industry being made to assume such destructive properties, under the magic wand of the chemist. The chemist now examines cotton in the new form, and trying to purify it, finds that it is soluble in ether. When left exposed, the ether quickly evaporates, and the gun-cotton retains a skin-like appearance. Surgeons seize the discovery of the chemist, and gun-cotton dissolved can heal the wounds it makes in its dry

state. Numerous applications follow, and man, forgetting his fear, uses the gun-cotton to silver mirrors, and to produce the portraits of his friends on glass, by a process speedy as the Daguerreotype. Another chemist, seeing how readily cotton unites with acids, investigates its power of combining with alkalies. He discovers that it does so, but notices that a contraction ensues in its fibres. Looms are not now required to make coarse calico fine, for immersion in soda makes it take the form of fine cambric. The alkaline calico washed in water loses its soda, but unites with water, and this in turn is displaced by colours when the calico is dyed, so that the calico assumes dyes of much greater intensity and brilliancy.

Analogous to this is the application of a well-known fact to the manufacture of flax cotton. As long ago as the time of Solomon, it was well known that acids produce an effervescence with carbonate of soda, for that wise King says, singing songs to a heavy heart is like pouring vinegar upon natron (mistranslated nitre). This old fact is now used to separate the fibres of flax, and give to it a cotton-looking appearance and properties. But this would have been insufficient as a practical result, had it not been that scientific discoveries had shown the existence of a class of bleaching compounds, termed hypochlorites, which enable a few hours to do the work of many weeks. These various facts, one acting upon the other, have led Chevalier Claussen to his interesting process.

These various discoveries of Schonbein, Mercer, and others, did not in any case arise from a direct practical search, but as offshoots of abstract investigation.

Antioch, in the beginning of the fourth century, discovered the importance, as a matter of police, of lighting its streets. But the discovery lapsed, and it was only in the middle of the sixteenth century that Paris lighted up her streets by fires made of pitch and rosin. Slowly did this matter of primary police creep on till the end of the last century, when it started forward with extraordinary vigour. Chemists had long observed that coal on being distilled produced a combustible gas, and the means of collecting and distributing various kinds of gas were among the common experiments of a lecture table. But it was not till

1792 that Murdoch employed coal gas to light up his offices at Redruth. Now gas has entirely substituted oil in the lighting of streets, but simply as a question of cost, the coals from which it is produced being cheaper than the corn necessary to form tallow. It by no means follows that gas is always the most convenient form of using a combustible. "It would certainly," says Liebig, "be considered one of the greatest discoveries of the age if any one could succeed in condensing coal gas into a white, dry, solid, odourless substance, portable, and capable of being placed upon a candlestick or burned in a lamp." A want is rarely clearly expressed by man that science does not administer to it; and already is the desire of Liebig accomplished. A mineral oil flowed out of coal in Derbyshire, and was obviously produced by a slow process of distillation from the coal. It contained solid paraffine dissolved in a liquid oil. Mr. Young, of Manchester, in examining the mode of its formation, found that paraffine, a solid waxy substance hitherto never produced from coal, could in reality be readily formed in commercial quantities by a slow and regular distillation. This, in fact, is "condensed coal gas," or, rather, it might be considered as a solid form of olifiant gas. It is therefore really the want of Liebig supplied. In forming coke, this product, dissolved in an oil of a similar composition, may readily be obtained; and useful products are made instead of those waste gases now thrown uselessly into the atmosphere. It might appear chimerical to you if I were to state many of the consequences which must follow if this discovery in its maturity be found as successful as it promises to be in its dawn; but it is not difficult to see that a cheaper and less carbonised coke could be burned in our domestic fires; and thus we might see a sun which now refuses to penetrate the sooty canopy of our cities.

Hour after hour might be employed in recording the triumphs of chemistry in its investigations into the play of the organic elements. Looking back no further than the last few years, you see how it has thrown open the most hidden processes of animal and vegetable life; how it has taught us to increase and economise the food of man. It is even yet the practice of those who have not followed her discoveries into the wondrous affini-

ties of the few simple organic elements to depreciate the importance of following their infinite creations. If, however, there were no other result from doing so than the one great achievement of having explained the ingredients in food used to build up the muscular frame and those employed in the support of animal heat, the importance of that discovery would have repaid all the labour of the past century.

Almost all the staple manufactures of this country are founded on chemical principles, a knowledge of which is absolutely indispensable for their economical application. In a few educational establishments and in some of our universities the alphabet of chemical science is taught; but it requires an institution such as this, devoted to a special object, to teach how to use that alphabet in reading manufactures. The extension of scientific and technical education is a want of the age. The old and yet widely-existing scholastic system of education introduced by the revival of learning in the fourteenth and fifteenth centuries is ill adapted to the necessities of the times. Erasmus would not now aid Cambridge in advancing the progress of England, nor would Vitelli make Oxford useful to the mass of its population. It would be of little use to the lagging progress of Italy even if Chrysoloras were again to teach Greek in its universities. Euripides and Thucydides cannot make power looms and spinning-jennies; for these Watts and Arkwrights are required. A Poggio may discover copies of Lucretius and Quintilian, without thereby producing a result equal to that of the smallest discoveries of a Stephenson or a Wheatstone. When will our schools learn that dead literature cannot be the parent of living science or of active industry? I do not underrate classical learning as an elegant accomplishment, or as a branch of human knowledge; I can rejoice as much in a good thought from Plato, or a happy allusion from Aristophanes, as I can in hearing a discussion on the philological affinities of the Indo-Germanic tongues; but I cannot understand why our sons of industry, destined to reap its harvests, should be placed in its fields of corn, having only been taught how to cull the poppies. "The great desideratum of the present age," says Liebig, "is practically manifested in the establishment of

schools in which the natural sciences occupy the most prominent places in the course of instruction. From these schools a more vigorous generation will come forth, powerful in understanding, qualified to appreciate and to accomplish all that is truly great, and to bring forth fruits of universal usefulness. Through them the resources, the wealth, and the strength of empires will be incalculably increased."

Institutions, such as this, are not substitutes for, but supplements to, the universities. It is the industrial training which we profess, and everything else is made subsidiary to that object. Not that we do or should forget abstract science, as such, because I believe the discoveries in abstract laws are of more real benefit to industry than their immediate applications. The technical man is, perhaps, of more use to himself and to his time and generation than he who discovers the abstract laws applied by the former to the purposes of industry; but it is the abstract philosopher who benefits all time, and confers universal and eternal benefit to society.

If I have convinced you that it is of infinite importance to a nation, not only to study science as constituting the foundation on which industry rests, but to promote the advancement of abstract science, the soul and life of industry, you will readily understand the importance of institutions the object of which is to infuse this life into special departments of technology. England has too long rested on the position which it has acquired as a manufacturing nation. This position was gained when local advantages gave an impulse to our practical national mind. But now that the progress of human events has converted the competition of industry into a competition of intellect, it will no longer do to plume and pride ourselves on our power of mere practical adaptations. It is miserable to see our industrial population glorying in their ignorance of the principles on which their manufactures depend, and vaunting their empiricism, or, as they term it, their "practice." Let us waken from this delusion, unless we prefer to—

> "Sit like spent and patient fools,
> Still puffing in the dark at one poor coal,
> Held on by hope till the last spark is out."

If England keep pace with other countries as a manufacturing nation, it must be by her sons of industry becoming humble disciples of science. At present her reliance in the "practical" or "common sense" of her population is the sunken rock directly in the course both of her agriculture and manufactures. On this subject Archbishop Whately has some excellent remarks. "By common sense," says he, "is meant, I apprehend (when the term is used with any distinct meaning), an exercise of judgment, unaided by any art or system of rules; such an exercise as we must necessarily employ in numberless cases of daily occurrence, in which, having no established principles to guide us, no line of procedure, as it were, distinctly chalked out, we must needs act on the best extemporaneous conjectures we can form. He who is eminently successful in doing this is said to possess a superior degree of common sense. But that common sense is only our *second best* guide,—that the rules of art, if judiciously framed, are always desirable when they can be had,—is an assertion for which I may appeal to the testimony of mankind in general, which is so much the more valuable, inasmuch as it may be accounted the testimony of *adversaries;* for the generality have a strong predilection in favour of common sense, except in those points in which they respectively possess the knowledge of a system of rules, but in these points they deride any one who trusts to unaided common sense. A sailor, e. g., will perhaps despise the pretensions of medical men, and prefer treating a disease by common sense; but he would ridicule the proposal of navigating a ship by common sense, without regard to the maxims of nautical art. A physician again will perhaps contemn systems of political economy, of logic, or metaphysics, and insist on the superior wisdom of trusting to common sense on such matters; but he would never approve of trusting to common sense in the treatment of diseases. Neither, again, would the architect recommend a reliance on common sense alone in building, nor the musician in music, to the neglect of those systems of rules, which, in their respective arts, have been deduced from scientific reasoning, aided by experience; and the induction might be extended to every department of practice. Since,

therefore, each gives the preference to unassisted common sense only in those cases where he himself has nothing else to trust to, and invariably resorts to the rules of art wherever he possesses the knowledge of them, it is plain that mankind bear their testimony, though unconsciously, and often unwillingly, to the preference of systematic knowledge to conjectural judgments." Practice and science must now join together in a solemn union, or the former will soon emigrate to other lands. The time is past when practice can go on in the blind and vain confidence of a shallow empiricism, severed from science "like a tree from its roots." The rudest sailor may steer his ship in the direction of a landmark, but without compass and sextant he dare not traverse the expanse of ocean. Ignorance may walk in the path dimly lighted by advancing knowledge, but she stands in dismay when science passes her; and she is unable to follow, like the foolish virgin having no oil in her lamp. Depend upon it, an empirical knowledge of practice is not the way now to succeed in the struggle of individuals, or in the struggle of nations. Intellect is on the stretch to get forward, and that nation which holds not by it will soon be left behind. For a long time, practice, standing still in the pride of empiricism, and in the ungrateful forgetfulness of what science has done in its development, reared upon its portal the old and vulgar adage, "an ounce of practice is worth a ton of theory." This wretched inscription acted like a Gorgon's head, and turned to stone the aspirations of science. Believe it not! for a grain of theory, if that be an expression for science, will, when planted, like the mustard seed of Scripture, grow and wax into the greatest of trees. The pressure and difficulties of the age, and the rapid advancement of intellect in continental nations, have been the Perseus to cut off this Medusa's head from the industry of England, and to fix it on the shield of Minerva, who turns to stone such as still believe that science should be ignored by practice; but, reversing that shield, wisely conducts those who would go further under her guidance. It is now rare to find men who openly avow, although they actually entertain, a belief in a necessary antagonism between theory and practice. Theory is in fact the rule, and practice its example. Theory is but the attempt to furnish

an intelligent explanation of what is empirically ascertained to be true, and is always useful, even when wrong. Theories are the leaves of the tree of science, drawing nutriment to the parent stem while they last, and by their fall and decay affording the materials for the new leaves which are to succeed.

I have now said enough to show you that it is indispensable for this country to have a scientific education in connexion with manufactures, if we wish to outstrip the intellectual competition which now, happily for the world, prevails in all departments of industry. As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they now are.

DEPARTMENT OF PRACTICAL ART

MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied to the Arts.

INDUSTRIAL INSTRUCTION

ON

THE CONTINENT.

(BEING THE INTRODUCTORY LECTURE OF THE SESSION 1852-1853.)

BY

LYON PLAYFAIR, C.B., F.R.S.

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The Intellectual Element of Production on the Continent.

By Dr. Lyon Playfair, C.B., F.R.S.

In two former Lectures on the subject of Industrial Instruction, I alluded generally to the efforts made by Foreign States to instruct their populations in that knowledge of natural forces which is so necessary at a period of civilization when the competition of industry has become a competition of intellect. It is, indeed, natural, that a perception of the necessity of industrial instruction should arise in those countries where the natural impulses to productive labour are either wanting or deficient, and where knowledge became essential to overcome the special resistances to manufacturing progress. To study the character and extent of the technical institutions abroad was, at the same time, to study not only their effects but also the causes which had led to their establishment; and I have, therefore, employed the short vacation, between our sessions, in visiting some of the principal institutions in Denmark, Prussia, Saxony, Austria, Bavaria, Baden, and France, for the purpose of making myself acquainted with the modes of instruction pursued in them. While endeavouring to communicate to you some of the impressions received by myself, it ought to be stated at the outset that the examination has been far from complete: the time spent by me in each of the institutions, though as much as I could give, was not always sufficient for a thorough investigation into the systems of instruction; besides which I visited them as a simple traveller, unarmed with any official recognition or aid, and depending for the requisite facilities of investigation only to an extensive acquaintance which I have the honour to enjoy in the countries referred to.* You will, therefore, understand distinctly, that my examination of the Technical schools abroad having no official character, has no claim to official completeness. Nor, in the short time at my disposal, could sufficient information have been collected to lay before you, had it not been for an extraordinary amount of courtesy and attention on the part of the directors of these institutions, and, in several cases, of the departments of Government with which they were connected.

Before entering into any details of the systems of instruction in foreign industrial institutions, it is requisite to show why they were required abroad, and why they are now necessary at home. In discussing this

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* In the Appendix, under the head of each country, will be found the names of some of those who furnished me with information.

argument in its general bearings, I may have to repeat views urged upon former occasions; but, as truths must be repeated until their consequences are realised, this is, perhaps, of little consequence, and will meet with a ready excuse.

Production, as understood in political economy, consists in the formation of utilities out of objects, which, either from their position or form, were of little use until subjected to the operations of industry. The principles involved in extractive, manufacturing, and even in distributive industry, are very similar in character, and involve the same factors. In industry, we can form utilities, but we cannot create properties. We can bring sand and soda together in the heat of the furnace, and we have formed the transparent body glass; but we have only used properties already existing in these materials, the acid character of the one and the alkaline character of the other having been employed to effect a chemical combination. In no one instance in production do we add a single property to matter, but we combine properties and create utilities. The success of a producer depends, therefore, to a great extent, upon his perceptive or empirical knowledge of properties and his power of using them so as to form utilities. But nature is very bountiful, and, in addition to properties embodied in matter, furnishes us with powers by which we can abridge human labour and more effectually overcome natural resistances to combination. Uncivilized tribes may, and often do, by observation, acquire a knowledge of properties equal to that enjoyed by nations more advanced; but they rarely understand those natural powers which form the strength and wealth of States that promote their study. Dacca and Chunderee can, by manual labour, make muslins better than our own; but the power loom and the spinning jenny were reserved for a nation which had studied the laws of mechanical science. Penelope required twelve slaves to prepare corn for her small household; while, as Chevallier remarks, the mill of St. Maur, with twenty men, grinds corn daily for the support of one hundred thousand soldiers.

Production involves as its factors, primarily, the material to be converted into an utility; then, the labour employed in the conversion; and, lastly, capital, which has been compared to the blood corpuscules, because it imparts vigour and activity to the vital processes, without itself taking direct participation or undergoing assimilation. The first factor—the raw material—is common in excellence to all producers, differing only in the relative cost of extraction and transport, or increased in price by arbitrary fiscal regulations. As locomotion improves, the local advantages of the country to which the raw material is indigenous become of less importance as an element in production; and industrial competition depends more upon labour—the second factor—than upon the first. This is certainly the case, or raw cotton could not be imported from America to be exported as calico. Malachite, sand, and wool could not come from Australia to go back as copper, glass, and broad cloth; nor could Dutch madder reach us to return to Holland as printed ginghams, or horse-hair and fat from Buenos Ayres and Russia to be returned as hair-cloth and soap. All this shows that the superiority of labour in one country does more than

compensate for the disadvantages arising from increased cost in the raw material.

Labour, however, is of two kinds—corporeal and mental, or, as Mill calls it—muscular and nervous. Mere muscular labour is to be had in all countries: the Egyptians, with their hoes and baskets, are found to be as good excavators as those we sent over with barrows and spades; but Egypt had to import the mental labour of a Stephenson before it ventured to produce a railway. The fact is every day more apparent, that mere muscular labour, in the present state of the world, is little better than raw material, and that both these are sinking in value as elements of production, while nervous or intellectual labour is constantly rising. The whole of industrial competition is now resolved into a struggle to obtain a *maximum* effect by a *minimum* expenditure of power. But this power is derived from natural forces, and not from brute strength: mental labour has engrafted itself upon muscular effort, and, by a healthy growth, has reduced the size and relative importance of the latter. Every new acquirement in the knowledge of natural forces is the acquisition of a new sense, which may be applied to production; and as every substitution of a natural force for muscular exertion depends upon a knowledge of the former, it surely requires no argument to prove, that the economical application of it must rest upon a perceptive and not merely empirical knowledge; or, in the language of the Wise King of Scripture, "If the iron be blunt, and we whet not the edge, then must we put to more strength; but wisdom is profitable to direct."

To this portion of the argument I have again to return; but an allusion to it was necessary, because these were the considerations which forced foreign countries to give an industrial education to their populations. Foreign States, partly from a deficiency of extractive labour, partly from an actual want of resources, were poor in the raw material or immediate means of production, and had, therefore, to rely chiefly on the proximate means. In the absence even of material for constructing machinery, it was not to be expected that tools, those essential proximate means of production, should quickly arise in an early stage of competition, although their economical application, when obtained, became of vital importance. Hence arose the obvious political necessity of developing rapidly the knowledge of natural powers, because these can only be effectually applied when fully understood.* This knowledge became, indeed, an intellectual tool of the

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* Sir John Herschel puts the argument very happily as follows:

"If the laws of nature, on the one hand, are invincible opponents, on the other, they are irresistible auxiliaries; and it will not be amiss if we regard them in each of these characters, and consider the great importance of a knowledge of them to mankind:

"I. *In showing how to avoid attempting impossibilities.*

"II. *In securing us from important mistakes in attempting what is in itself possible, by means either inadequate or actually opposed to the end in view.*

"III. *In enabling us to accomplish our ends in the easiest, shortest, most economical, and most effectual manner.*

"IV. *In inducing us to attempt, and enabling us to accomplish, objects, which, but for such knowledge, we should never have thought of undertaking.*"

greatest importance in a country which had yet to acquire experience. In our own land, the rapid development given to production by our richness in natural resources raised at the same time a vast amount of experience, and art advanced before science. This experience was often produced by trial and error, and was attained by great expenditure of time and capital; but, when arrived at, afforded much help to production. Hence we see many producers in our own country, practising their arts by the aid of empirical experience only, little guided by scientific laws. Hence also has arisen an overweening respect for practice, and a contempt for science; as if man could better use the powers of nature by stumbling against them in the dark, rather than by reverentially seeking them in the open light of day. But continental producers, being behind us in the race of competition, and having industries to create, preferred to profit by our empirical experience, and then pass us by their applied knowledge; for they have virtually adopted, as a principle of State, the aphorism of Bacon, "The knowledge and power of man are coincident; for, whilst ignorant of causes, he can produce no effects. Nature is only to be conquered by submission; for that which in speculation stands for the cause, is what in practice stands for the rule."

Perhaps, until lately, the balance of advantages was in favour of this country; for, with our cheap natural resources in material, and its difficulty of transmission to other countries, the practical aptitude of our population in availing themselves of the benefits of experience, and the power of our capital in directing labour and importing intellect, when that was not to be found sufficiently cultivated at home, we have had impulses given to production which have communicated to it an impetus sufficient to carry it for some time over the obstacles raised by the superiority of the intellectual element of labour abroad. But that a rapid change is passing over the world has long been seen by statesmen and by all thinking men, — a change which must effect immense alterations in the productive powers of all nations. In the words of Prince Albert, "Whilst formerly discovery was wrapt in secrecy, the publicity of the present day causes that no sooner is a discovery or invention made, than it is already improved upon and surpassed by competing efforts. The products of all quarters of the globe are placed at our disposal, and we have only to choose which is the best and cheapest for our purposes, and the powers of production are entrusted to the stimulus of competition and capital. . . . . The distances which separated the different nations and parts of the globe are gradually vanishing before the achievements of modern invention, and we can traverse them with incredible ease. The languages of all nations are known, and their acquirement placed within the reach of everybody. Thought is communicated with the rapidity and even with the power of lightning." These circumstances are daily lessening the value of mere experience,* which arising in

* By the term *experience* in this lecture, I allude only to the empirical knowledge which arises in the growth of practice; it is not used in its true metaphysical or scientific meaning.

one country soon becomes the property of another. For many years, foreign States, acting upon the facilities of communication, have expended annually large sums in sending highly enlightened men to our country for the purpose of culling from our experience, and of importing it into their own land; and we see the effect of the experience, thus readily acquired when united with the high development of mental labour, in the rapid growth of new industries abroad. We still hold to mere experience as the sheet anchor of this country, forgetful that the moulds in which it was cast are of antique shape, and ignorant that new currents have swept away the sand which formerly held it fast, so that we are in imminent risk of being drifted ashore.

In fact, this is the great question at issue between England and foreign States. With us there is a wide-spread jealousy of science, and a supposed antagonism between it and practice. Mere empirical experience is of slow growth, and, after all, is only adapted for the particular conditions in which it was attained: it is a crutch which will support a lame man, but will not suffice to enable him to run a race; it resembles in its growth the slow propagation of an unaided flora throughout a land, which might be quickly disseminated, if science were allowed to gather its seeds and throw them broadcast over the country. It is only experience, aided by science, that is rapid in development and certain in action. In this country we have eminent "practical" men and eminent "scientific" men; but they are not united, and generally walk in paths wholly distinct. From this absence of connexion there is often a want of mutual esteem, and a misapprehension of their relative importance to each other. The philosopher is apt to undervalue the dignity of productive industry, while the practical man sees, in the absence of utilities, only the visionary speculator. Hence the former too often stands apart in self-reliance on his usefulness to the world, and like Themistocles, when asked to play, is inclined to reply, "Though I cannot fiddle, I can make a little village a great city." Abroad, the scientific element of production is carefully nurtured, because the truth is there fully recognized, that nothing is so fertile in utilities as absolute abstractions; but it is known also to be essential to industry, that there should be a race of men to translate these abstractions into worldly utilities, and who can solicit nature, in language understood by her, to lend her powers for the fulfilment of practical ends. The creation of this class of men was, as has been shown, a necessity of foreign competition; for, without this superiority in the intellect-element of labour, it was impossible to overcome our advantages in the cheapness of material and in the abundance of capital.

But this forced perception of the necessity for industrial instruction has enabled the continent to seize the *growing* element of production, while we are left in possession of the *decreasing* one; and while we continue to rely upon local advantages and acquired experience, we allow a vast power to arise abroad which is already telling against us with wonderful effect. It is most essential that we should furnish this element of strength to our producers, and not imitate the rustics in the fencing school described by

Demosthenes, who always after a hit guarded the part that was struck, but not before.

In raising the intellect-element of production, continental States have passed through grave errors, from which they have only lately escaped; and it will be useful for us to profit by and avoid them. To understand the evils into which a wrong direction of education led them, it is necessary again to refer to the separation between abstract and practical science. In former Lectures I have endeavoured to show how important it is to a nation to develope abstract science; it is not, therefore, likely that I shall be misunderstood as depreciating it in the remarks which I am about to make. Rather than again urge this point, I quote the high authority of Mill from his "Political Economy."

"In a national or universal point of view the labour of the savant or speculative thinker is as much a part of production, in the very narrowest sense, as that of the inventor of a practical art; many such inventions having been the direct consequences of theoretic discoveries, and every extension of knowledge of the powers of nature being fruitful of applications to the purposes of outward life. The electro-magnetic telegraph was the wonderful and most unexpected consequence of the experiment of Oersted, and of the mathematical investigations of Ampère: and the modern art of navigation is an unforeseen emanation from the purely speculative, and apparently merely curious, inquiry by the mathematicians of Alexandria, into the properties of three curves formed by the intersection of a plane surface and a cone. No limit can be set to the importance, even in a purely productive and material point of view, of mere thought. . . . . Intellectual speculations must be looked upon as a most influential part of the productive labour of society, and the portion of its resources employed in carrying on and remunerating such labour, as a highly productive part of its expenditure."

In this country we have a theoretical belief but no practical faith in these views. We have taken good care not to imitate the woman in Æsop's fables, who believed that a double feed would induce her hen to lay double the quantity of eggs, not dreaming that the hen would get fat and lay none at all; but we have produced nearly the same result, by neglecting to feed our philosophers, and we are surprised that the golden eggs of discovery are now so rarely laid among us.

In Germany especially, and in France also, the error was committed, of supposing that abstractions would naturally give birth to utilities, without intermediate practice to aid the birth. Hence education was made wholly of an abstract character, and the cumulation of an abstract instruction of the masses became positively pernicious. Large numbers of men were reared in abstract, physical, and mental philosophy, for whom the channels of industry offered no outlet; they naturally pressed upon the Government which had stimulated them to acquire abstract knowledge, and a gigantic bureaucracy was forced upon the State. The evil increased to such an extent that in some States 60 out of 1,000 of the population were

in Government employment. A mere university education* in abstract philosophy, or the secondary instruction of the Grammar schools, was found to be a hot-bed for the production of bureaucrats, and only indirectly useful to industrial production. The error was perceived by many, and found expression in various ways: thus Count Von Seidlitz, in leaving his fortune for the promotion of industrial education, quaintly says in his will, "I should commit a sin against the Holy Spirit if I left my money so as to induce young men to study, in order that they might continue to turn round the tread-mill of the State."† To relieve the State from an overwhelming bureaucracy, and at the same time to give a rapid impulse to the growth of manufactures, numerous channels were formed, by which abstractions might be drawn off for the support of utilities. The "Real" system of education then arose in Germany, and is now extending under this or other names to all European countries, except our own. In the schools professing this system the realities of modern life are taught in preference to the languages and customs of the classical ages. This, perhaps, too rapid transition of the secondary instruction, forced realities into the "Gymnasia" or Classical schools themselves, and these became more adapted for modern wants. The Real schools were found to act favourably in diminishing the exclusive attention to the study of abstract philosophy, but they did not suffice to give a quick impulse to industrial development; hence arose the widely extending system of "*Gewerbe*" or Trade schools, and, as the culminating points of these, the Polytechnic Institutes or Industrial Universities.

This circumstance is generally lost sight of by some modern writers of repute, who vehemently warn you to shun the poison of continental education, but neglect to tell you, that when the cause of its hurtfulness was discovered, the poison was extracted. They take the dying embers of a fire which burned for some time too fiercely, and blowing them again into life, they profess that the heat continues to be equally scorching; they tear evils out of the past, and, dressing them up in a modern garb, try to make you believe that they still live, although it is only the results effected by them that are yet seen in the passing generations: they trust to our native prejudices, and try to scare us with what Carlyle would call "the ghosts of extinct giants."

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* As an instance of the extent to which abstract education is even yet cultivated, there were, in the universities of Germany and Switzerland, in the session of 1851–52,—18,810 students; of whom,—

3,450 were theologians.
6,761 jurists and economists.
4,182 medical men.
2,644 "philosophers," or students of the abstract sciences, chiefly the mental.
1,773 unclassified.

—"Allgemeine Zeitung," 6th October 1852.

† "Ich würde eine Sünde gegen den heilig Geist begehen, wenn ich mein Geld dazu bestimmte junge Leute zum studiren zu verleiten, um den Rossmühlengang des Staats Weiter zu treten."

It is the peculiarity of the industrial system of instruction that it can scarcely over-educate a population, as is so frequently done in professions, because industry is universal and of infinite proportions. The streams which water the vast plains of industry are never too full, for by a little diversion they can be made to irrigate and render fertile new and yet uncultivated tracts. Although the channels leading from an abstract to a practical education are constantly augmented by the policy of foreign Governments, they do not exhibit any sign of being in excess, nor are the waters kept back by a deficiency of outlet. It is, in fact, almost impossible that they should be so, for after all they terminate only in the world's ocean of industry, where they are sure to be absorbed. Do we not see this in the fact that our glass-makers, porcelain-manufacturers, our calico-printers, and others, have been obliged to receive from abroad that intellectual element of manufacture which they could not obtain at home—a right policy for industrial producers, but a miserable one for the State which had neglected to cultivate it within itself?

The State does not deem it expedient to rely on a supply of sailors from foreign countries for defending its own possessions; it prefers to send out more sailors from its nurseries than our own demands require, allowing them rather to enter into foreign service than check their growth at home. We know that, though to some extent losers by this, on the whole we are great gainers. Precisely the same feeling operates with continental countries, who would rather have an excess of the intellectual element of production than a deficiency, and who do not object to the employment of that excess in England, not only because it is a premium to its growth among themselves, but also because it forms a connecting channel through which our advanced experience flows back to them in return for the intellect abstracted.

The very fact that many of our most enlightened manufacturers have intellectual foreigners to aid them in the management of their works, or in their productions, shows that the continental system of industrial instruction is producing results which require the most serious attention of those who would see our industry continue to enjoy that prominent position in the rapidly changing state of the world, which it acquired when the transition was slow, when facilities of locomotion did not exist to the extent that they now do, and, therefore, when mere experience and local advantages, aided by the occasional irruption of science, was sufficient to keep pace with the march of events. I therefore proceed to show you the nature of that instruction, so far as I can in a Lecture of this kind.*

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* In the body of the Lecture generalities only are treated of; the details are frequently to be found in the Appendix. It may here be stated, that no description of Schools of Mines is given, because these have been already fully described by various authors; a memoir specially devoted to them will be found in vol. i. p. 485 of the "Memoirs of the Geological Survey, &c."

INDUSTRIAL INSTRUCTION OF PRUSSIA.

I would remind you, that the secondary education of Prussia is of three kinds; and consists of the *Gymnasia*, or Classical Schools; the *Real* Schools; and the *Gewerbe*, or Trade Schools.

The Gymnasia teach many more *realities* than the Grammar schools of our country, but nevertheless they are chiefly classical. The Real schools profess a general education, like the Gymnasia, but substitute the modern languages for the ancient; preserving, however, Latin, and giving more prominence than the Gymnasia to the physical sciences. In the provinces of the Rhine, in other words, in the chief manufacturing districts of Prussia, the Real schools are the best attended, and perhaps in Berlin also; but, upon the whole, the Gymnasia, which are indispensable for admission to the University, still retain their high position as means of affording a secondary education; and they hold their places more firmly since they have begun to introduce *realities* into their courses. With both these systems, however, I have nothing to do in this Lecture further than to draw attention to the fact, that the general character of all secondary education in Germany is tending towards giving instruction in the wants of the nineteenth century, and not stopping at that considered sufficient in the thirteenth, as many of our classical schools do.

The third system of secondary education, the Trade schools, is, however, directly technical in character. Pupils are not admitted into them until they are fourteen years of age, and it therefore frequently happens that they have had a *real* education previous to their admission. Every pupil, before entering them, must have had a good primary education in his own language, must thoroughly understand the elements of arithmetic, and the mensuration of plane and solid bodies, and must be able to show that he is a good free hand drawer. The course of instruction consists of two years, and the time given to each object of study is seen in the following scheme:—

SCHEME OF THE TRADE (PREPARATORY) SCHOOLS OF PRUSSIA.

UNDER CLASS (1st year).

	Hours in a week.
Planimetry *	4
Algebra, to equations of the first degree	3
Practical arithmetic	4
Physics	4
Chemistry	4
Free drawing	7
Linear drawing	9
	35

* Plane Geometry.

UPPER CLASS (2nd year).

a. Winter Session.

Continuation of algebra—trigonometry	3
Stereometry * and descriptive geometry	3
Practical calculation	2
Mechanics and machinery	3
Laboratory work, and repetitions in chemistry and physics	4
Mineralogy	2
Architecture, contract works, and plans	3
Free drawing	7
Linear drawing	9
	36

b. Summer Session.

Continuation of descriptive geometry and conic sections	3
Application of algebra and trigonometry to the solution of questions in planimetry and stereometry—land surveying	3
Practical calculations (extraction of roots, logarithmic practice, and calculations of capacities in bodies)	2
Machinery and mechanical technology	3
Chemical technology	4
Mineralogy	2
Architecture and building plans	3
Free drawing, modelling	7
Linear drawing	9
	36

In looking at the scheme of instruction, you will scarcely remember that these Trade schools are in fact only preparatory to the Central Industrial Institute of Berlin; but you may naturally inquire,—Have such schools arisen in the necessity of the people, or by a political perception of their requirement on the part of the Government? The answer is, that the Government only grants one half the funds necessary for their annual support, and that the towns in which they are situated must furnish the rest, and build the school-houses. No such school is founded unless upon the petition of a locality for a grant in aid; so that they are, in fact, based upon the same principles as our own Schools of Design, with this difference, that the localities do more and the Government less than in this country. There are now 26† of these Trade schools in Prussia, viz., 7 in the provinces of the Rhine, 5 in Westphalia, 3 in Prussian Saxony, 2 in Brandenberg, 2 in Pomerania, 3 in Prussia Proper, 2 in Silesia, and 1 in Posen. They are therefore situated so as to exert a direct influence on the chief industrial parts of Prussia. The instruction is not gratuitous, the charge varying from thiry shillings to three pounds annually; and yet about 1,200 scholars are every year receiving the comprehensive technical knowledge offered by these professedly elementary schools. The instruction and examinations are

* Solid Geometry.

† Two of them, however, are only in the act of formation, viz., those at Coblenz and Dusseldorf.

watched by Government, through Commissioners appointed by the Minister of Trade; and the best pupils have the privilege of passing to the Central Institute at Berlin, to which I have now to refer.

THE TRADE INSTITUTE OF BERLIN.

The Trade schools of Prussia are mainly intended for tradesmen or small producers, such as masons, carpenters, well-sinkers, millwrights, &c.; while the Trade Institute professes chiefly the instruction of engineers, civil or mechanical, architects, and managers of factories and chemical works. The foundation, however, of this Central Institute is different from all others which I have seen on the continent, and is in fact now in a transition state. Not only is its instruction wholly gratuitous, but about 50 out of its 170 pupils receive 30*l.* annually from the Government. The annual cost of the school to the State is 7,000*l.*, of which 1,500*l.* are devoted to the support of poor pupils, and 1,000*l.* are spent in travelling expenses, both professors and students being occasionally sent to foreign countries to acquire a knowledge of recent inventions and new industrial improvements. The chief peculiarity of this institution was in its being originally confined to the education of workmen, who, in addition to the principles of their trade, were even taught their mechanical craft in extensive workshops. It is now, however, acknowledged that this was an error, and that the practice of an art can only be learned, satisfactorily, in the workshops of industry. The whole organization of the school has, therefore, been recently changed, and its instruction is now assimilated in character to that given by the other higher industrial institutions of Germany; but, as its past experience is instructive, I have described its present and former systems in the Appendix (App. A.) Now the instruction is devoted to the higher class of producers, and among its professors are the well known names of Drückenmüller, Wolff, Dove, Rammelsberg, Magnus, Wiebe, Fink, Freiberg, Pohlke, Kiss, and Boettlicher. As might be expected from men of such eminence, the character of the instruction, though eminently practical, is at the same time highly scientific. The course of instruction is for three years, and the students, before being admitted, must have a "maturity certificate" from a Secondary school, or submit to an entrance examination. Accordingly, no student comes to this Central College without being well acquainted with the elements of mathematics, physics, chemistry, and drawing. This previous knowledge is of the greatest importance, as it relieves the professors from teaching the elements, and enables them to devote their whole time to the applications of the sciences. The course of instruction extends over three years, but in the second and third years the students divide into special branches, adapted to the three divisions of (A) mechanics and engineers, (B) chemists, (C) architects and builders. The following list of subjects will give an idea of the extent of the instruction :—

COURSE I.

Hours in a week.*		
8.	*a.* Pure mathematics	Stereometry and spherical trigonometry; descriptive geometry; algebra, differential and integral calculus; analytical geometry; practical calculations.
6.	*b.* Physics.	
6.	*c.* Chemistry.	
8.	*d.* Linear drawing, particularly constructions by descriptive geometry, shaded constructions, and perspective; then machinery-drawing.	
10.	*e.* Free and architectural drawing.	

COURSE II.

6.	*a.* Pure and applied mechanics, illustrated by the higher mathematics.	
4.	*b.* Repetitions and specialities in physics and chemistry.	
3.	*c.* Mineralogy.	
7.	*d.* Materials used in building, and laws of architecture.	

These are the courses common to all students; but, engrafted upon these, come the separate courses for the different professions.

A. *For Mechanics.*

In Course II.:

9.	Machinery in an extended course; materials used in machines; separate parts of mechanism; machines used in building; composite machines; practical exercises.	

In Course III.:

12.	*a.* Continuation of machinery; steam engines and other machines driven by power; practice in projection.	
—	*b.* Railways and buildings.	
4.	*c.* Technology.	
—	*d.* Practice in the machine-workshop (3 days in the week).	

B. *For Chemists.*

In Course II.:

8.	*a.* Chemical technology.	
	b. Analytical chemistry.	
—	*c.* Practice in the laboratory (2 days in the week).	

In Course III.:

—	*a.* Laboratory work (daily).	
4.	*b.* Machinery drawing and projections.	

C. *For Builders and Architects.*

In Course II.:

8.	*a.* Freehand and architectural drawing; projections in building, both in stone, brick, and wood.	
—	*b.* Modelling in clay.	

In Course III.:

9.	*a.* Projects, plans, and estimates for buildings.	
—	*b.* Stone cutting (6 months).	
—	*c.* Heating and warming arrangements (6 months).	
8.	*d.* Plans and contracts of factories, &c.	
4.	*e.* The machinery class (with the chemists).	
—	*f.* Modelling of buildings in plaster, wood, and stone.	

These courses, except in those cases which are marked, extend over two sessions of 6 months each.

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* These hours are only approximative; the workshops and laboratory employ all the spare hours which are not here indicated.

The plan of instruction in this school is, to communicate all such information as may be required by a particular manufacturer, although not directly included in the limits of his profession. Thus it is considered necessary that the chemist should be able to construct plans, make estimates, and understand the principles of machinery, in order that he may know how to express his wants to engineers or builders, and be able to see that the contracts are not excessive in price. As the instruction is given gratuitously by the State, only those students are allowed to remain in the institution who give evidence of satisfactory progress. An efficient plan of final examination for the granting of general certificates has not hitherto existed in this school, although now about to be introduced; still the students are in great demand by manufacturers, and it is rare to find men who go out with good class certificates waiting any considerable time for employment.

In Prussia there are several other technical institutions for engineers, architects, and commercial men; but a description of them is without the limits of my present Lecture, or at all events, cannot be introduced in the time at my disposal.

SAXONY.

The Secondary schools of Saxony, like those of Prussia, are of three kinds, viz., Gymnasia, Real, and Trade schools. There are nine Gymnasia,* seven of them being supported by the localities, and two by Government. At present there are only four Real schools,† but three others are being founded. The Trade schools are three in number, and are situated at Cheimnitz, Plauen, and Zittau; they are chiefly supported by Government, the communes finding the site. The first costs the Government about 1,000*l.* annually; the two latter between 400*l.* and 500*l.* each. Public opinion is still divided as to whether the Gymnasia or Real schools give the best general secondary education, but there is a general agreement as to the advantages of the Trade schools, which are steadily increasing in the number of their pupils. They carry their instruction so far that their pupils may at once pass into the higher division of the—

Polytechnic School of Dresden.

This school is placed in a large and handsome building, and is well organized and conducted, although its annual revenue, amounting to 2,600*l.*, is so much less than that of the Industrial Institute of Berlin. The school is divided into three parts, viz., the Under school, the Tech-

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* The Gymnasia are placed as follows: two in Dresden, two in Leipsic, and one in each of the following towns: Freiberg, Zwickau, Bautzen, Meissen, Grima. The two latter are supported by Government, the others being communal.

† There are two Real schools in Dresden, one in Leipsic and one in Anaberg.

nical or Upper school, and the Architectural school. It has been found expedient, as in the Institute at Berlin, to make certain fundamental classes common to all students, and then to divide the instruction into specialities, those of the Technical school being—

A. Mechanists.
B. Civil engineers.
C. Chemists.

The Under part of the school commences generally with students of sixteen years of age, and lasts for three years. The instruction given is as follows; the number of hours devoted weekly to each subject being given:—

LOWEST DIVISION.

CLASS III.

Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
5	5	Stereometry and trigonometry.	2	2	Laws of projection,
5	5	Algebra.	2	2	Plan drawing.
4	4	Experimental physics.	6	6	Ornamental drawing.
3	3	German.	2	2	Natural history or practical geometry.
3	3	French.			

CLASS II.			CLASS I.		
Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
4	4	Analytical geometry (in the plane).	4	4	Analytical and descriptive geometry.
5	5	Mechanics.	5	5	Mechanics.
4	4	Theoretical chemistry.	5	5	Machinery.
4	4	Mineralogy.	3	3	Mechanical technology.
2	2	Architectural science.	4	4	Technical chemistry.
2	2	Practical geometry (Class III.)	2	2	German and logic.
3	3	German.	2	2	French.
3	3	French.	3	3	English.
6	6	Machine-drawing.	4	4	Machine drawing and perspective.
4	4	Ornamental drawing.			
4	2	Field surveying (practical).	4	4	Architectural drawing.
4	2	Plan drawing.			

In addition to these there are for—

Winter.	Summer.	—
Hours.	Hours.	
6	6	A. Modelling in wood, and special hours of instruction in machine drawing.
4	2	B. Field surveying, and continuation of practical geometry,
6	6	C. Larger number of hours in the laboratory.

You have now seen what is considered to be the elementary knowledge requisite for the Upper or Technical division of the school, which the students enter at nineteen years of age, remaining two years. The instruction in this division is now as follows:—

UPPER OR TECHNICAL DIVISION.

CLASS II.			CLASS I.		
Summer.	Winter.	—	Summer.	Winter.	—
Hours.	Hours.	*For all Students.*	Hours.	Hours.	
5	5	Differential and integral calculus.	4	4	Higher (analytical) mechanics.
3	3	Mechanical technology.	4	4	The higher physics.
2	4	Geology.	4	4	Astronomy.
2	2	German and logic.	2	2	National economy.
2	2	English.	2	2	Popular jurisprudence.
2	4	Book-keeping.	2	2	German and logic.
½ day	—	Geological excursions.	2	2	English.
		Section A.			*For A.*
3	3	Mill machinery and construction.	3	3	Theory of motive powers.
3	3	Higher geodesy.	9	9	Projects for machines.
9	9	Projects for machines.			
		Section B.			*For B.*
3	3	Higher geodesy.	3	3	Brick and stone-work (methods and contracts).
4	4	Roads, railways, and hydraulic engineering.	1 day	4	Practical surveying.
1 day	4	Practical working in surveying.			Plan drawing.
9	9	Plan drawing.	9	9	Building projects.
		Projects for machines and for hydraulic works.			
		Section C.			*For C.*
12	16	Laboratory practice.	16	16	Laboratory practice.

It will be observed, with some surprise, that the native language, German, forms a part of the instruction, even in the highest class; and the reason given for this appears to be satisfactory. It was found that mere technical instruction was apt to contract too much the views of the students, and that they had little inclination afterwards to subjects of general interest; but now, through the German class, the students are kept interested in history and polite literature, so that they go out from the school not less instructed technologists, but more cultivated men. Instruction in the modern languages, besides its technical importance, is also made subservient to this end. The school possesses collections and workshops on a moderate scale, but no large machine workshop, as in Berlin. In the vacation, the students, with the sanction and aid of the Government, are engaged in practical operations; some being placed on the railways to work locomotives and aid in the general traffic, while others are sent to coal-works, mines, iron furnaces, &c., and, generally, under the charge of the Professors. The number of students at the time of my visit was 220, each of them paying 4*l.* 10*s.* annually, except a small number who were relieved from payment on the ground of poverty; but, in addition to this, there were 27 who devoted their time to drawing and modelling. The number of Professors in the Technical school is 21. (App. B.)

Besides the Technical school, there is, in the same institution, a school of Architecture, possessing 7 professors and 85 students, during the last session. The instruction given was as follows :—

LOWER CLASS.		UPPER CLASS.		REPETITION CLASS.	
Hrs.		Hrs.		Hrs.	
6	Architectural science.	4	Building.	2	Building economy and contract.
5	Arithmetic.	4	Carpentry.	2	Repetition of architecture.
5	Geometry.	6	Statics and mechanics.	6	Statics and mechanics.
3	Industrial physics.	3	German.	2	German.
4	German.	2	Ornamental drawing.	2	Ornamental drawing.
2	Ornamental drawing.	4	Perspective.	2	Perspective.
4	Projects.	6	Architectural drawing.	16	Projects and plans.
6	Architectural drawing.	4	Projects and building plans.		

The "Maturity" examination, which each student must pass before he obtains a certificate, requires very high qualifications on the part of the pupils, and is conducted before a Royal Commissioner, specially appointed for this purpose, and in the presence of numerous persons who are invited to be present.

AUSTRIA.

Austria has but lately established the *Real* system of Secondary instruction, which is, therefore, only in course of development; and, as yet, she has no Trade schools corresponding to those of Prussia and Saxony. On the other hand, she has several provincial Polytechnic colleges, viz., in Pesth, Prague, Gratz, Brun in Moravia, and Lenberg in Galicia; the number of students at these amounting to about 4,000. In all of them the standard of instruction is said to be high; but I have not seen them. I must, therefore, confine myself to the Polytechnic school at Vienna, one of the largest institutions of this kind in Germany, the number of students in the Systematic part of the school being, at the time of my visit, 1,637, the total number in all sections being 3,378. The State gives from 60,000 to 80,000 florins annually for its support, and the school funds amount to about 30,000 more, so that the total revenue may be taken at between 10,000*l.* and 11,000*l.* The education is gratuitous; the only sum charged being a matriculation fee of 8*s.* There are only about 25 exhibitioners, who receive sums varying from 10*l.* to 20*l.*

The organization of this institution is peculiar, and requires a little explanation. It is divided into four sections proper, and one section for popular instruction; these sections are:—

A. *Technical*, comprising the physical and mathematical sciences, in their industrial application.

B. *Commercial*, for instruction in all matters involved in the occupation of a merchant.

C. *Preparatory Division*, for the instruction of those who have entered without sufficient preliminary knowledge.

D. *Trade Drawing.*

E. *Popular Section*, for instructing workmen on Sundays and holidays.

As I have only to make a passing allusion to the two last sections, they may be taken first in order. The habits of foreign nations on Sunday have led to the formation of Sunday schools, for secular and not for religious knowledge; and these I found in every large town on the continent. Last year the attendance of workmen at the Sunday school in connexion with the Polytechnic Institution at Vienna was as follows:—

For mathematics	190
Mechanics	116
Experimental physics	211
Chemistry	133
Drawing	731

Besides this general instruction on Sunday there are extraordinary lectures in mathematics, German, French, English, Bohemian, Turkish, Italian, and stenography.

In section D. or Trade drawing there are seven professors, and the instruction extends from four to five hours daily. The attendance at the time of my visit was as follows :—

Preparatory drawing	184
Manufacturing drawing	86
Drawing for metal work	76
Machine drawing	14

I must, however, pass on to the systematic sections of the institution. The course of instruction generally lasts for five years, the student, being in his sixteenth year before he enters the Technical division, must show evidence of possessing a sufficient amount of elementary knowledge. There is a little want of system in the division of studies, the student being left to choose his own lectures ; although the Director offers to advise him when required. I am, therefore, unable to divide the courses into years ; but the following scheme gives the number of hours devoted in each week to the subjects :

PREPARATORY CLASS.		TECHNICAL SECTION.		COMMERCIAL SECTION.	
Hrs.		Hrs.		Hrs.	
10	Mathematics.	10	Mathematics.	5	Mercantile science.
3	Physics.	10	Differential and integral calculus.	3	Commercial law.
3	Natural history.			4	Style and composition.
5	Style and composition.	5	Descriptive geometry.	5	Mathematics and algebra.
10	Drawing.	10	Drawing.	2	Raw materials and products.
		5	Practical geometry.*	2	Geography, trade, &c.
		5	Mechanics.	5	Book-keeping.
		7½	Architecture.		
		7½	Engineering.		
		5	Mechanical technology.		
		5	Geology and mineralogy.		
		5	Botany.		
		5	Physics.		
		5	General chemistry.		
		4	Technical chemistry.		
		5	Agriculture..		
		5	Ornamental drawing.		

* This scheme does not, however, give a fair representation of the subjects taught, many being included under one title, as, for example :—

Practical geometry includes { Planimetry. Surveying. Measuring heights, and levelling. Plan drawing.

Mechanics include { Laws of machinery. Construction of machines. Machine drawing.

Architecture includes { Architectural Science. " " Economy. " " Book-keeping and contracting. " " Drawing.

Engineering includes { Road and Railway engineering. Hydraulic engineering. Book-keeping and estimates. Engineering drawing.

Technical chemistry includes { Fermentation. Soap-making. Colours, dyeing, calico printing. Tanning. Starch, sugar-making, &c.

Drawing in all these cases is taught with a view to the speciality.

The experience of the voluntary choice of lectures has led to the following division, as that which is found best adapted to engineers, although its adoption is not compulsory upon them:—

Year I.	Year II.	Year III.
Mathematics. Technology. Drawing.	Differential and integral calculus. Physics. Descriptive geometry. Geometrical drawing.	Mechanics. Machine drawing. Practical geometry. Plan drawing.

Year IV.	Year V.
Architecture. Chemistry. Mineralogy.	Roads and railways. Hydraulic engineering. Engineering drawing. Book-keeping. Technical chemistry. Mineralogy.

This scheme is given as an example of the division adopted; but it is varied to suit the art for which the pupil studies, and the course is arranged between him and the director. The collections of this institution are ten in number, and well adapted for the purposes of study. (App. C.) The models for these are made by workmen on the premises, but there is no general workshop as in Berlin. The laboratory is well arranged, and consists of several rooms admirably fitted up, a special allowance of 120*l.* being annually made for the purchase of material, &c. The number of professors, teachers, and assistants in the institution amounts to 58, exclusive of the house staff. It will, therefore, be apparent, that the institution is on a large scale, and that the instruction is comprehensive in its character, although not so systematic as in some of the other German schools. The examinations for certificates are not made in the regular or open manner of those to which I have already alluded; but it is understood that new regulations with regard to them are under consideration. Nevertheless, I was assured by Chevalier de Burg, the late director, and Professor Redtenbacher, that, notwithstanding the large number of students, the demand for them by industrial establishments is greater than can be readily supplied.

BAVARIA.

In Bavaria there are no Real schools, and only a few of the Gymnasia introduce realities into their courses; but there are 26 Trade schools, or, in fact, one such school for every large town. I find by the statistics of 21 schools, which I have obtained, and proportioning for the five, of which I have no account, that there are above 3,000 pupils annually obtaining the high education given in these Trade schools. The schools are supported by the Commune, aided, when necessary, by the Province. The management of the schools and appointment of the professors rests with the locality; but the Government exercises a supervision, and sends Com-

missioners annually to examine and report upon them to the Minister of Trade. The courses extend over three years; and as the entrance age is twelve, the pupil at fifteen may pass into the higher Polytechnic Colleges. Of these there are three, one being in Munich, another in Nurnberg, and the third in Augsburg. They are chiefly supported by Government, which allows, however, only 39,000* Bavarian florins, or 3,250*l.*, for their support; and the number of pupils amounts to 481, the professors being 34 in number. In addition to these higher Polytechnic schools, there are two Commercial schools, also supported by Government (at Nurnberg and Furt), and there is a Building school at Munich, which is chiefly intended for the instruction of master masons and carpenters (see Appendix D). Besides these, there are Industrial schools for workmen on Sundays and holidays; and the pupils attending them cannot be less than from 8,000 to 10,000.

The system of industrial instruction in Bavaria dates from 1833, and so satisfied is the Government with its effect that they continue to support and extend it with great liberality. It would be impossible in this Lecture to describe to you the details of the systems of instruction pursued, even in each of the three Head Colleges; and I confine myself to simply giving you the scheme of the Munich institution, referring you to the Appendix for fuller descriptions. I ought, however, to state, that it would require a union of all three Colleges to make really one Polytechnic Institute; as each of them practically, though not professedly, gives a leaning to special branches of the Arts; thus, Munich chiefly devotes itself to civil engineers and architects; Augsburg, to mechanists; and Nurnberg, to chemists; I confine myself, however, to the Institution at Munich, as an illustration. It is situated in a large and commodious building, possesses admirable collections, especially one of physical apparatus, and has a modelling and sculpture workshop in great activity. The number of its professors and teachers is 16, and of pupils 307, of whom 83 are foreigners. Its course of general instruction extends over three years, but engineers take a special fourth year's course. The scheme of instruction is as follows:—

Course I.		Course II.	
Hours.		Hours.	
7	Mathematics.	7	Analytical mechanics.
7	Physics.	6	Machinery and machine drawing.
7	Machinery and machine drawing.	2	Plan drawing.
2	Plan drawing.	7	Chemistry.
3	Descriptive geometry.	7	Differential and integral calculus.
2	Ornamental drawing.	4	Architecture.
2	Catholic religion.	3	Building materials.
2	Protestant religion.	3	Electro-magnetism and telegraphs.

Course III.		Engineering Course.	
Hours.		Hours.	
7	Applied mechanics.	12	Roads and bridges (in winter).
4	Geodesy.	12	Hydraulic engineering (in summer).
4	Machinery and machine drawing.	12	Constructions and projections; building; surveying.
6	Analytical chemistry.	8	Architectural drawing and modelling.
6	Applied architecture.		

* Munich receives 18,000 florins, Augsburg 9,000, Nurnberg 12,000; and in addition, they may receive from 800 to 1,200 florins (1 florin = 1*s.* 8*d.*) each from pupils.

Certificates of proficiency are granted, the examinations being made before a Royal Commissioner, who has to report to the Board of Trade on the efficiency of the institution. The architecture of Bavaria, and the excellent engineering which is observed there, is said to be, in a great measure, due to this school; and it is undoubted that its pupils are in great demand, and fill important positions in industry.

GRAND DUCHY OF BADEN.

In the Duchy of Baden the Secondary schools are of three classes, the Gymnasia, the High *Bürger*, and the Trade schools, but the latter do not possess the same high standard of instruction as in other places; and the students of the *Bürger* schools act as feeders to the Great Polytechnic Institution, while the Trade schools are chiefly devoted to the education of workmen. The Polytechnic school of Carlsruhe is perhaps the most efficient one in Germany; and as its constitution and organization are probably more nearly allied to any similar institution that might arise in this country, I will enter into its description somewhat in detail. The school is now about 18 years old; but its present state and organization have resulted from the experience of the last ten years. It has two main divisions, viz.:—

A. Preparatory section, consisting of three mathematical classes.
B. The *Fach* schools, or schools of specialities, consisting of—
   a. Engineering.
   b. Architecture.
   c. Forestry.
   d. Chemistry and technology.
   e. Mechanical technology.
   f. Commerce.
   g. Post-office.

The Polytechnic school is under the Minister of the Interior, and is managed by a director, annually elected by the professors from among themselves, and by another self-elective machinery, which appears to be unnecessarily complicated.

a. A special council of teachers, consisting chiefly of the principals of the Special schools.
b. A general council of all the teachers.
c. An executive council.
d. An auditor.
e. A secretary.

Although there are seven Special schools, several of the professors teach in more than one; but dividing them into their respective sciences, we find the following large staff of teachers:—

Mathematics	7	Drawing	2
Natural and physical sciences	5	Ornamental writing	1
Architecture	6	Modelling, carpentry, and machine working	3
Engineering	2		
Forestry	3	General subjects	10
Sculpture	2		

Thus there is a staff of 41 teachers to about 330 students, of whom 112 are foreigners.* This institution differs from most schools in Germany by being to a great extent self-supporting, the Government grant being only 32,000 florins, while the expenses are above 50,000 florins. It does, indeed, seem extraordinary that with a revenue of little more than 4,000*l.* (4,166*l.*), this institution is able to accomplish as much as it does. The cost to each student is about 6*l.* annually. The periods of the courses vary according to the speciality to be studied, as will be seen by the schemes of instruction.

Mathematical or Preparatory Course.

(Course, 3 years.)

Class I.		Class II.		Class III.	
Hrs.		Hrs.		Hrs.	
1	Catholic religion.	2	Catholic religion } with Protestant religion } Class I.	4	Descriptive geometry.
1	Protestant religion.	4	Analysis and higher equations.	3	Analytic geometry.
6	Arithmetic and algebra.	2	Plane and spherical trigonometry.	5	Integral and differential calculus.
4	Geometry.	2	Analytical geometry.	5	Elements of mechanics.
8	Introduction to descriptive geometry.	8	Descriptive geometry.	4	Practical geometry.
2	German.	5	Statics.	6	General chemistry.
6	French.	4	Physics.	4	Mineralogy and geology.
4	General history.	2	German (second course).	3	French (third course).
4	Drawing.	3	French (second course).	3	English.
1	Writing (ornamental).	2	Drawing.	4	Drawing.
		4	Modelling.	–	Modelling.

Special Schools.

A. *Engineering school.*

(Course, 3 years.)

Course I.		Course II.		Course III.	
Hrs.		Hrs.		Hrs.	
3	Higher analysis (in winter)	12	Civil engineering (higher)	12	Projects and contracts.
3	Higher mechanics (in winter)	10–12	Machinery.	4	Higher architecture.
8	Civil engineering.	2	Jurisprudence (summer).	3	Higher geodesy.
12	Machinery.	4	Plan drawing.	24	Practical surveying.
4–6	Practical architecture (drawing and modelling).				
3	Ethics.				
4	Plan drawing.				
3	English.				

B. *Architectural school.*

(Course, 4 years.)

Course I.		Course II.	
Hours.		Hours.	
4	Spherical trigonometry and analytical geometry.	4	Technical chemistry.
4	Differential and integral calculus (first course).	3	Ethics (in winter).
5	Elementary mechanics and hydraulics.	4	Figure drawing.
2	Literature and style.	5	Drawing.
4	Descriptive geometry (second course).	8	Modelling.
5	Drawing.	5	Ornamental drawing.
8	Modelling and workshop.	7	Projects and contracts.
5	Ornamental drawing.	3	Technical architecture, architectural statics.

* Of these 112 there were 72 Germans from other States, and 40 "*Ausländer*," consisting of English, French, Swiss, Dutch, Belgians, Hungarians, Poles, and one East Indian.

Course III.		Course IV.	
Hours.		Hours.	
6	Roads and hydraulic engineering.	4	Mineralogy and geology.
6	Practical construction of the above.	2	Jurisprudence.
6	Laws of machinery.	4	Modelling and ornamenting.
3	Æsthetics.	5	Shadowing and plaster casting.
4	Architecture.	3	Monumental architecture.
5	Ornamental drawing.	5	Plans and contracts for great buildings.
4	Modelling.	5	Painting and perspective.
5	Projects for dwelling-houses.	3	Archæology.
3	Higher architecture.		

C. *School for Forestry.*

(Course, 2 or 3 years.)

Preparatory Class.		Course I.		Course II.	
Hrs.		Hrs.		Hrs.	
4	Mathematics.	4	Practice in "forest mathematics."	3	Agricultural chemistry.
4	Physics.	4	Technical chemistry.	2	National economy.
4	Botany.	3	Mineralogy and geology.	3	Preservation of forests.
4	Zoology.	4	Botany.	2	Forest statics.
2	German.	3	Meteorology; soils.	7	Forest economy.
		3	Forest trees (Botany of).	2	Forest laws.
		6	Forests.	3	Forest police.
		4	Forest economy.	2	Forest rights and sports.
		2	Wood taxation.	–	Excursions.
		2	Road-making.		
		4	Practical geometry.		
		–	Scientific excursions in the woods.		

D. *Chemical school.*

(Course, 2 years.)

Course I.		Course II.	
Hours.		Hours.	
6	General chemistry (in winter).	4	Special technical chemistry.
4	Technical chemistry.	3	Analytical chemistry.
7	Botany and zoology.	3	Special subjects in chemistry.
4	Mineralogy and geology.	4	Mineralogy and geology.
4	Practical geometry.	2	Popular engineering.
4	Popular mechanics.	3	Ethics (in winter).
2	Mechanics applied to transport.	–	Working in laboratory.
4	History.	–	Languages.
6	Book-keeping and commercial law.		
–	French, English, drawing, workshops.		
–	Chemical laboratory.		

E. *Mechanical school.*

(Course, 2 years.)

Course I.		Course II.	
Hours.		Hours.	
6	Construction of machines.	6	Machinery and technical mechanics.
6	Machinery (Laws of).	6	Construction of machines.
6	Workshop.	6	Mechanical workshop.
4	Physics.	4	Technical chemistry.
3	Higher analysis (second course).	4	Engineering (second course).
3	Higher mechanics (in winter).	6	English.
4	Engineering.		
–	French.		

F. *Commercial school.*

(Course, 1 year.)

Hours.	—	Hours.	—
4	Commercial law.	1	History of commerce.
2	Book-keeping.	2	German.
2	Correspondence.	4	French.
3	Commercial arithmetic.	3	English.
2	Products (Knowledge of).	2	Calligraphy.
2	Commercial geography.	2	Drawing.

Postal school.

(Course, 2 years.)

Course I.		Course II.	
Hours.		Hours.	
3	Arithmetic.	2	Political arithmetic.
2	Geography.	2	Geography.
4	Mechanics (Popular).	2	National economy.
4	Physics.	2	Jurisprudence.
4	General history.	3	Commercial contracts.
2	Religion.	2	Mechanics applied to transport.
4	French and French commerce.	4	German and Composition.
2	German.	5	French.
2	Calligraphy.	3	English.
		2	Calligraphy.
		3	Ethics and Æsthetics.

You will observe, however, that this institution differs from all those which we have already examined by splitting its instruction into seven different specialities, and that therefore it deserves the name of a Polytechnic Institution more than the others. The mode of instruction in all the schools is by lectures, practical working in the laboratory, the carpentry and machine shops, and in surveying; while at the same time examinations and repetitions are very frequent. The formal certificates of the Special Technical schools are said to be in the highest estimation, and command immediate employment to the possessors.

EXTENT OF THE INSTRUCTION IN GERMANY.

I have now concluded the description of the Industrial schools of Germany, so far as my personal knowledge extends. There is, however, an excellent Polytechnic Institution in Hanover which I have not had time to visit, and therefore regret that I am obliged to omit its description. Reviewing what has been said, and adding a fair proportion for the districts not visited, it is quite certain that at least 13,000 well qualified students *

* This is exclusive of the workmen in the Industrial Sunday schools. The number of pupils at these cannot be under from 30,000 to 40,000; although I give this number only as an approximative estimate made from the proportion of systematic pupils to Sunday pupils in the schools from which I have obtained the statistics. For a popular explanation of these schools, and their general effect upon industry, I would refer to Zschokke's excellent little volume, "Labour stands on Golden Feet."—Groombridge and Co., London.

are being every year systematically instructed in the industrial institutions of Germany; and when you consider the character of that systematic instruction, if you agree in the general argument with which the Lecture commenced, you will be convinced, that the time has come when England must begin to raise an intellectual force to do battle with that mighty one which is rising everywhere around her. But I must now pass to France, our worthy rival in industry.

FRANCE.

It is well known that France encourages to a great extent the industrial instruction of its producers. The *Ecole Polytechnique* of Paris, the *Ecole des Ponts et Chaussées*, and the *Ecole des Mines*, have been too often described to require more than a passing reference to them. But as they are chiefly for the instruction of Government *employés* they do not necessarily act immediately on private production. At the same time it is not to be forgotten that it is the principle of the French Government to act upon its own perception of right by instructing the population, even before formal demands have been made, on the part of the public, for the benefit which is thus conferred. It is therefore the more surprising, that the middle classes for some time urged their want of an institution for the industrial instruction of their producers, without carrying conviction of its necessity to the Government. Impelled by the urgency of the want, a private institution was raised ; and the feeling in its favour was sufficiently strong to induce a capitalist to embark a large sum of money in founding it. This private institution, raised in a capital where the public schools are altogether under the Government, proved that it was a necessity of the times by its immediate and eminent success. Thus rose the *Ecole Centrale des Arts et Manufactures*, now the most important industrial institution in France. It possesses the most eminent men of France as its professors, and it has reared those who promise to be her future brightest ornaments. As a commercial speculation it has been singularly successful, and it still remains under the business direction of the original enterprising capitalist, M. Lavallée. The Government now gives to it a certain number of exhibitions to educate poor students of extraordinary talents, and the Councils General of twenty-nine departments of France also do the same. The appreciation of its importance to France may best be seen in the Report of the Commission of the Chamber of Deputies appointed to inquire into the budget :—

" You know, gentlemen, this useful establishment, founded in 1829, by the association of eminent professors, with the intention of forming civil engineers, the directors of works, the chiefs of workshops and factories. This private institution, which by its importance rivals in excellence our first public establishments, has created and put in practice a complete system of industrial education. It is at the same time a supplement to our Polytechnic School, and an addition to our various applied schools. Such an institution ministers to one of the first necessities of the age, therefore

its success is complete. This is confirmed both by the unanimous opinion of the first manufacturers of the country and by the ease with which all the pupils educated at it have received employment."

The school possesses 40 professors and teachers, and 300 students, each of whom pay 36*l.* annually. The number of the latter is only limited by the size of the building, and it is in contemplation to remove to one considerably larger. The courses extend over three years, and are compulsory on all, but in the second year the practical operations divide into two parts, the one general and the other applicable to one of the four following specialities:—

A. Mechanists.
B. Engineers.
C. Metallurgists.
D. Chemists.

Students are not admitted until they are eighteen years of age, and they must furnish proof of possessing a good elementary knowledge of the sciences (App. E). The courses of instruction are as follows:—

Year I.	Year II.	Year III.
Descriptive geometry. Analytical geometry and mechanics. Transformations of motion. Physics (general). Chemistry (general). Chemical manipulation. Hygiene and natural history applied to the arts. Drawing.	Descriptive geometry. Industrial physics. Mechanics. Materials used in construction of machines. Analytical chemistry. Industrial mineral chemistry. Public works. Geology. Manufacture of iron and steel. Technology (cordage, textile materials, cutting wood, stone, &c.).	Steam engines. Railways. Hydrostatics. Construction of machines. Chemical preparations and organic analysis. Industrial organic chemistry and agriculture. Architecture. Mining. Furnaces and foundries. Technology (mills; oil-making; spinning; felting; milling; potteries, &c.).

It will be seen by the above scheme, that after the first two headings in the second and third years, the subjects are parts of corresponding courses, and in practice they are professed every alternate year to the second and third years' students combined. The greatest attention is paid to drawing and design, much time being devoted to them. The students have to make plans to prove their progress; as, for example, a beet-root sugar factory being wanted, the student, from his knowledge of the conditions of the manufacture, must draw out a plan of works, giving estimates, &c. of its cost. Certificates of proficiency are granted after the most severe public examinations extending over many days. I was fortunate enough to be present while these were proceeding, and admired the extent and accuracy of the information possessed by the pupils. But you will ask for the proof of the efficiency of this kind of education for manufacturers; and I reply by stating, that a certificate from this institution is equivalent to assured success in life. Its pupils invariably pass into the most important positions in industry, and not only France, but Spain, Belgium, and England have learned to value them, as we see by the ready manner in which the manufacturers of these countries secure their services. Allow me to give you a few statistics of about 550 of the certificated students, whose occupations are so important that their histories can be traced.

Of this number the following division may be made, all of the occupations being high and responsible :—

Agriculture	18	Chemical arts	57
Architecture, canals, &c.	39	Civil engineering, &c.	56
Railroads	119	Machinery	30
Professors and teachers	42	Metallurgy and mining	79
Textile manufacturers	36	Paper, commerce, salt-works	22
Public works	53		

But the question of its utility may be put in another way: if foreign countries find the pupils of this institution useful, do they send over their own sons for instruction ? To this I reply, that more than 600 foreigners have been educated at this school, and, in analysing its books for statistics to this effect, I was surprised to find, in addition to representatives of the known industrial countries of Europe, numerous students both from North and South America, from Turkey, the Antilles, Hayti, the Mauritius, Madras, Ceylon, Gibraltar, &c. Spain and Belgium send over regularly considerable numbers to this school, and England this year has five or six of her subjects who were obliged to go abroad for that comprehensive instruction which they could not get at home. Experience has shown that it is precisely those countries which do not possess a system of industrial instruction that send the largest proportion of foreigners to be educated there.

Besides this institution which is devoted to the industrial instruction of the middle classes, you all know of that princely establishment the *Conservatoire des Arts et Métiers*, the object of which is, both by its splendid museums and by the lectures of the eminent men who profess there,—and of whom it is only necessary to mention the names of Morin, Dupin, Pouillet, Péligot, Moll, Blanqui, Wolowski, Regnault, and Payen,—to instruct the working classes in industrial science, and to draw public attention to all new discoveries in industry.

This institution is, however, so well known by its beautiful and instructive collections, that I am spared the necessity of describing them.

Under Colonel Morin, the distinguished director who has introduced such life and activity into the Conservatoire during the last few years, there are three provincial industrial colleges, each supported by Government at an expense of 300,000 francs, or 12,000*l.* These colleges are situated at Chalons, Angers, and Aix, and contain between 200 and 300 students each, who are boarded and educated at the public expense. The students being of a lower class than those who go to the Ecole Centrale and educated chiefly as men who may aspire to be master workmen. Accordingly, five hours every day are devoted to study, and seven hours to the workshops. Many of the pupils of these institutions obtain Government employment, and those who have passed their examinations find ready occupations as foremen, draughtsmen, and clerks of works. I have not personally seen these provincial schools, but Colonel Morin, the present director, has assured me of their high state of efficiency.

BELGIUM.

In a lecture on Continental industrial instruction it would be wrong to omit allusion to this important producing nation, though I have not recently visited its institutions. The Belgian Government, however, accepting the lesson of the Exhibition, and being convinced of the necessity of industrial instruction to its producers, has recently sent Commissioners to various countries for the purpose of inquiring into this subject, and with the view of immediately establishing a college at Antwerp, and perhaps also at Brussels. Only a few months since M. de Cocquiel made an educational tour in this country, on behalf of the Government; and he could not conceal his astonishment at the character of the instruction with which we had contented ourselves in this country of production. Belgium, however, though it has depended hitherto to a great extent upon the educational resources of the *Ecole Centrale* of Paris, nearly 100 of its manufacturers having been educated there, has not at the same time been altogether negligent in this direction. The University of Liège has special schools of mines, and of arts and manufactures, which have been in operation since 1838. The pupils are admitted to them only after a strict examination in proof of their having the necessary elementary knowledge. The following requirements for the examination of the pupils in each year will also indicate the course of study:—

A. Section of Mines.

Year I.	Year II.	Year III.
Applied mechanics. Industrial physics. Mineralogy. Mineral analysis. Assaying. Drawing, applied to machinery, &c.	Geology. Mining (1st Part). Inorganic technical chemistry. Metallurgy (1st Part). Drawing, applied to geology and mining.	Mining (2d Part). Plan drawing. Industrial architecture. Metallurgy (2d Part). Drawing, applied to the previous subjects. Industrial economy. Mining legislation. English. German.

B. Section of Arts and Manufactures.

a. Arts and Manufactures.

Year I.	Year II.	Year III.	Year IV.
Statics and dynamics. Elementary physics. General chemistry and manipulation. Descriptive geometry. Drawing.	Applied mechanics. Industrial physics. Mineralogy. Mineral analysis. Assaying. Drawing applied.	Geology. Mining (1.) Chemistry. Metallurgy (1). Drawing applied to preceding subjects.	Mining (2). Plan drawing. Metallurgy. Industrial architecture. Industrial economy. Practice in making plans and contracts. Drawing.

b. Mechanics.

Year I.	Year II.	Year III.
Statics and dynamics. Elementary physics. Inorganic chemistry. Descriptive geometry. Practical drawing and shading. Workshop practice. Design.	Applied mechanics. Machinery drawing and shading. Industrial physics. Workshops.	Industrial architecture. Construction of machines. Projects for machines. Workshops. Machinery drawing.

In addition to these courses, there are others by *Répétiteurs* on design, topography, and surveying, differential and integral calculus, analytical mechanics, &c.

It is therefore obvious that Belgium cannot be classed as a country which has neglected the industrial instruction of its producers, although it is now about to give it a fuller and more efficient development.

I have now only a few words to say with regard to other countries, because, with the exception of Denmark, I have no personal knowledge of their industrial institutions. In Madrid there is an institution and museum similar to the Conservatoire des Arts et Métiers, but for the systematic instruction of the middle class of producers the *Ecole Centrale* of Paris is still used by Spaniards.

With regard to Scandinavia it will not be necessary to detain you long. It is well known that there is an excellent institution in Stockholm which has exercised the most material influence on Swedish industry ; but though anxious to inspect it this year, I found that the time at my disposal would not permit me to do so. In Denmark the secondary education is tending much to the Real system, notwithstanding the present excellent combination of classical learning with *realities* in the Gymnasia. The Polytechnic Institution of Copenhagen was founded in 1829, and is chiefly supported by Government, which gives 12,000 rixdollars annually, while the fees of the students amount to about 2,000 more. The total revenue of the institution does not therefore reach 1,600*l*. The number of students is not great, there being at present only 44 matriculated "polytechnics," and about 60 other students attending special lectures, while there are 9 professors.

The course of instruction divides itself into three specialities ;

A. Mechanical section.
B. Scientific section.
C. Agricultural section.

The courses of instruction for each of these divisions are seen in the following schemes :

A. *Mechanical Section.*

Year I.			Year II.		
Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
5	4	Mechanical physics.	9	9	Mathematics.
5	—	Chemical physics.	2	—	Descriptive geometry.
5	—	General chemistry.	6	6	Mechanical technology.
7	8	Mathematics.	5	—	Industrial physics.
4	4	Descriptive geometry.	5	—	Technical inorganic chemistry.
—	4	Optics.	—	4	Machinery.
9	—	Geometrical drawing.	9	—	Machine drawing.
—	6	Machine drawing.	—	12	Projects for machines.
—	12	Laboratory practice.			

Year III.		
Winter.	Summer.	—
Hours.	Hours.	
8	—	Machinery.
9	—	Mechanical technology.
12	18	Construction of machines and workshops.

B. *Scientific Section.*

Year I.			Year II.		
Winter.	Summer.	—	Winter.	Summer.	—
Hours.	Hours.		Hours.	Hours.	
4	4	Mathematics.	4	4	Mathematics.
5	–	Mechanical physics.	–	6	Mechanical technology.
5	–	Chemical physics.	–	4	Machinery.
5	–	General chemistry.	5	–	Industrial physics.
–	5	Organic chemistry.	2	–	Geology.
–	5	Chemical analysis.	4	–	Zoology.
–	4	Optics.	5	–	Technical organic chemistry.
2	–	Crystallography.	–	4	Botany.
–	2	Geognosy.	12	12	Laboratory work.
–	12	Laboratory work.	6	6	Drawing of apparatus.
–	6	Drawing of apparatus.			
9	–	Geometrical drawing.			

Year III.		
Winter.	Summer.	—
Hours.	Hours.	
6	–	Technical organic chemistry.
9	–	Mechanical technology.
12	whole time.	Laboratory work, drawing, &c.

C. *Agricultural Section.*

Year I.			Year II.			Winter III.	
Winter.	Summer.	—	Winter.	Summer.	—	Winter.	—
Hrs.	Hrs.		Hrs.	Hrs.		Hrs.	
5	–	Mechanical physics.	5	–	Industrial physics.	5	Technical organic chemistry.
5	–	Chemical physics.	4	–	Zoology.	–	Laboratory.
5	–	General chemistry.	–	4	Botany.	6	Drawing.
–	5	Inorganic analysis.	5	–	Technical chemistry.		
–	12	Laboratory.	12	12	Laboratory.		
6	6	Drawing.	6	6	Drawing.		
–	3	Agricultural chemistry.	4	–	General agriculture.		
			–	5	Breeding of cattle.		
3	–	Agricultural implements.	–	3	Systems of agriculture.		

The Polytechnic Institution of Copenhagen, as will be seen from the above scheme, has an extended system of instruction; but, nevertheless, it has not been very successful in its operations. One reason assigned for this is, that its instruction is too abstract, and neither special enough, nor sufficiently technological; but the other and perhaps true cause is, that Denmark is not yet a large manufacturing country, and that in absence of all fuel except wood and peat, and of the main raw materials used in production, its manufactures are only likely to be of slow growth. Accordingly there are not sufficient outlets in Danish industry for a large number of pupils of such a school, and accordingly I find that only 66 men have taken diplomas between 1829–1848, of whom 25 are in Government employment, 23 in manufactures and workshops, and the remainder as teachers in Real schools, &c.

Since 1848 about 24 more pupils have passed, and are well employed. In fact, the present natural outlet for such an institution in Denmark is in civil engineering, and to this many persons think it should be mainly

directed. At the present moment extensive changes in its organization and objects are in contemplation, although unfortunately the idea of converting it into a military school seems to be the prominent one.

I would refer to the Appendix (F.) for the account of a most interesting institution, named "The Technical Institute of Copenhagen," which is chiefly devoted to the instruction of workmen, of whom 520 were in regular attendance last session. The institution is, in fact, a school of design, but is remarkable for the detailed applications of art, there being a class for almost every trade; as, for example, for brick-builders, carpenters, cabinet-makers, tin-plate-workers, lock-makers, gas-fitters, goldsmiths, bookbinders, carpet-makers, &c. But besides design, mathematics, physics, the nature of building materials, and other subjects of a like nature, are taught. This institution is supported by private subscriptions, and the expenditure does not amount to 400*l.* annually.

Before concluding, it may be useful to draw attention to some general points of interest in the systems of instruction which we have examined. In all of them there are differences with regard to the mode of giving instruction, but they are almost uniform in the feeling that the object of Industrial schools is only to teach a pupil how to become an intelligent manufacturer, without attempting to make him one. They content themselves with communicating to him a knowledge of the principles upon which his technical art depends; but for its practice he must go to the workshops of industry. Some of the institutions, as, for example, the Trade Institute of Berlin, endeavoured at one time to teach practice in workshops attached to the institution, but this plan, as might have been anticipated, was found to be of little advantage, and it is now abandoned by almost all the schools, only one or two being still found hovering on the outskirts of this error. In addition to the folly of attempting to teach the practice of an art within the confines of an institution chiefly devoted to other objects, it was found to be highly detrimental to the progress of the students, who were glad to escape from the mental labour of the classes to the muscular labour of the workshops.

This is the point upon which the producer and the promoter of industrial instruction are likely to disagree, unless they thoroughly understand each other; and I am therefore anxious that there should be no mistake on this subject. We do not think that in such schools we can furnish a substitute for the practical training of the workshop, the factory, or the office of engineer; but we do think, that a producer possessing a knowledge of natural forces will become a practical man in a shorter time than without it, and that he will know how to turn his practice to the best account. Let me instance the case of a surgeon, as an illustration. For a long time surgery was only an empirical art, carried on by monks and Jews, until the Council of Tours, in 1163, prohibited the former from operating, and then it fell into the hands of barbers and smiths. No one doubts that much useful experience was acquired by them; and their empirical experience assumed the character of a system at a time when Edward IV. allowed no one but barbers to practise

in London. It was not till the eighteenth year of George II. that barbers and surgeons were finally separated from each other, and that the latter were allowed to fix the standard of their own qualifications. All the fears expressed by manufacturers now were expressed by the barbers on the eve of their separation from the surgeons, and so alarmed were the former for the safety of the public in the hands of the latter, that they got a provision introduced in the deed of separation by which surgeons are strictly prohibited from exercising "the feat or craft of barbery and shaving." But does history tell us of any dread evils which arose from giving surgeons more of a scientific and less of a rule of thumb education? No one ever dreamt of turning out a young man from a lecture-room as a ready-made surgeon; he must have had hospital practice before he is launched into his profession, and much general practice before his course in life is assured. But it is not now pretended by any one that his education in science renders him less fit to avail himself of the experience of this practice; on the contrary, it is admitted that it is essential for him, and that he benefits more by the practice than he would have done had he not had the science. The quack or the empiric depends upon experience alone, and often works real cures, but he fails as often, because he is ignorant of the cause of his success, and an application of the same practice under other conditions may produce fatal results. "Science renders the powers of nature the servants of man, whilst empiricism subjects man to their service. The empiric, placing himself on a level with an inferior or unconscious being, employs but a small portion of his power for the advantage of society. He permits effects to govern his will, whilst, by a true insight into their hidden causes, he might govern them."—(Liebig.)

One other illustration will suffice. In the most critical time of the Peninsular war, the Duke of Wellington found himself deficient in the number of military engineers, and commissions were freely given to Cambridge mathematicians. The wise Commander knew that men possessed of the necessary scientific knowledge could be trained to practise more quickly than those who had it not. He did not dream of giving to a mathematical theorist the charge of the works at Badajoz or Almeida, but he felt that experience would more quickly flow into a mind fitted to receive it than into one which had not been thus prepared.

The promoters of industrial instruction do not, therefore, offer it as a substitute for practical training, but consider it to be a means by which the latter can be made more efficacious. They do not think that the seed will grow, unless the land is well tilled by the practical farmer, but they offer to manure the land first, and the ploughing-in the manure will enrich the soil and render it more productive.

Another point, common to the higher industrial institutions abroad, is, that they do not communicate elementary knowledge in science, but only teach its applications to industry. They originally experienced the same evil that we have at present in this school (Government school of Mines, &c.), that the pupils came untrained in science, and that the time was spent in teaching its elements, instead of its applications. But gradually raising their standard of knowledge for admission, the public perceived what was

required of them, and came with sufficient preliminary acquirements. Some idea may be formed of the state of education by the fact, that pupils are not generally admitted into the Upper Technical class of mechanics, physics, and machinery, unless they have passed examinations in integral and differential calculus. This condition for admission has a twofold advantage; first, that it enables professors to devote all their time to the industrial applications of science; and then, that the Industrial institutions, instead of acting as antagonists to those for general education, actually give them the greatest impulse, and are their most powerful supporters.

We must also observe the favourable results which arise from the close connexion of the sciences and of art in the same institution. Mathematical science is not studied and kept apart as a separate branch of knowledge, as is too frequently done in some of our most important schools and colleges, but she is used as the handmaid and interpreter of all the other sciences, and even of art; and it is with this view that so much time is devoted to her study. Perhaps Aristotle was too limited in his views when he said, "Physics and mathematics make practice;" but Bacon was certainly not in error when he wrote, "For as physical knowledge daily grows up, and new actions of nature are disclosed, there will be a necessity for new mathematical inventions." And what a commentary on this text is our present knowledge in astronomy, navigation, logarithms, surveying, the theory of tides, the wave theory of light, the attraction of spheroids, and of the mass of the earth! In all the courses of the institution, even in architectural and machinery drawing, mathematics give powerful aid. Drawing, in the same way, is used throughout the courses as a handmaid to every science and art, and is not kept in an isolated position, as in our Schools of Design. Hitherto the practice in them has been to teach students to draw, though it is difficult to know how they could be taught to design for arts, regarding which they have had no instruction either as to their wants or their resources.* Abroad, the Schools of Design form part of the Schools of Industry. In our country we are doing much in a fragmentary and dispersed way, which a little union and system would make far more important to industry than it is now.

The comprehensive system of instruction pursued abroad is found to have a most happy effect on the future career of the student. The manufacturing chemist leaves the school with a sufficient knowledge of the principles of machinery to guide him in its management, or to aid him in the expression of his requirements. He can plan and sketch the buildings, machinery, and apparatus which he may require, and he has been taught enough of building and contract work to know whether the plan of the architect is sufficient, and the charges of the builders within moderation. The architect does not end his education with drawing elevations and planning interiors; but chemistry and physics have shown him how to test the qualities of his building materials, and have taught him the principles

* Mr. Cole, the present enlightened Superintendent of the Department of Practical Art, has begun to remedy this defect, as far as regards the Central School.

of ventilation, lighting, acoustics, and drainage, while mathematics enable him to calculate the stability of his structures. These illustrations are sufficient, because the schemes of instruction indicate the knowledge which it has been found advantageous to communicate to the producer in each art.

The mere fact that industrial schools are increasing abroad, and that the number of their pupils is constantly augmenting, is of itself a sufficient proof of their influence on industry, even had we no proofs more direct than these. But it is, indeed, extraordinary that the proofs are already so palpable; for it might have been expected that, at least, the time of one generation would have been required to develope their effects. The interests of a nation extend much beyond the interests of the one generation which forms its present population, and the statesman will feel sure that the effects already in action will operate with a much increasing power in the future. The sun of knowledge does not expend its light and heat-giving rays in vain. You do not measure the snows on the hills by the little streams which trickle from their summits; but, taking timely warning from them, you are glad to escape the terrors of the thundering avalanche. I do earnestly desire to convince you of the necessity for immediate action; for delay, until the urgency is more palpable, may be ruinous; we see a stream flowing from the fountain-head of knowledge, and though we pause on the brink, and gaze, it is not likely to run out, but will continually increase in power—

> ". . . . . Sapere aude,
> Incipe. Vivendi recte qui prorogat horam,
> Rusticus expectat dum defluat amnis: at ille
> Labitur, et labetur in omne volubilis ævum."

You will perhaps think, that in combating some of the ordinary objections to a system of industrial instruction, I have raised up phantoms only for the pleasure of laying them; and you would be right in this supposition, were it not that the question has been frequently, but no doubt unintentionally, misrepresented and misunderstood. After all, the question resolves itself into a consideration of extreme simplicity, viz., Whether it be wiser to employ natural forces in production, with a knowledge on the part of the producers of what they are, or with a total ignorance of their nature? or, in other words,—Whether it be better to solicit nature to help us, in language intelligible to her, and to which she never refuses to reply, or to assault her with a rude empirical jargon which grates upon her ears, and causes her to turn from us? There is no escape from the simplicity of the position, or from the palpable fact, that continental nations are proceeding in the first conditions of the question, and our country in the second. We cannot blink the fact, that the paths of competition are becoming narrower and steeper, and that foreign nations are learning how to walk in them with open eyes, while we are still trusting to the old expedient of experimentally grappling at objects to pull us up, trusting that, if one support fail, we may catch hold of another before we fall. Who is likely to gain in this game? Let the proverb answer: "A wise man's eyes are in his head, but the fool walketh in darkness."

To all this style of reasoning there is but one reply, viz., that England, relying on her experience only, is still in advance in the race of competition.* So she is, on the whole; but is she as much in advance in the quality (not the quantity) of her products, as she was twenty, nay even ten years since? On the contrary, do we not know positively that other nations are closing fast upon her by taking shorter cuts? It is true that we find them sometimes halting in the race; but never mind that—"A cripple in the right way may beat a racer in the wrong."

Let us deal, however, in sober facts, and not in metaphors, and see in what language they speak to us. Is there any significance in the fact that we chiefly relied on the invention and science of a foreigner to tell us the duty performed by the different machines in the Exhibition? What conclusion are we to draw from the following remarks in the official report of the jury on machines? "In reporting upon the hydraulic machines exhibited, it is impossible to refrain from adverting to the general neglect of those elementary principles of scientific knowledge on which the perfection of such machines always depends, and, in some cases, the whole usefulness in an economical point of view. The Exhibition affords positive evidence of the sacrifice of a large amount of capital, and of much mechanical ingenuity, due simply to the ignorance of certain acknowledged principles of hydraulic science. In adverting to this fact, the jury cannot but observe that the success with which the principles of mechanical science in their application to practical questions are beginning to be cultivated in France appears in the superiority of the French hydraulic machines. It is but reasonable to expect that the superiority which the French have attained in certain branches of industry, by their attention to the art of design, will eventually appear, through the agency of the *Ecole des Arts et Métiers*, in the scientific character of their machines." A striking fact, illustrating the inefficiency of mere experience, was shown by the trials in the Exhibition; for, notwithstanding the great antiquity of water pumps, and the experience which England has had in them, it was found, on subjecting the most approved forms to trial, that from 55 to 80 per cent. of their effective power is actually *lost;* a fact which experience did not suspect, but which science has proved, and at the same time indicated its remedy.

In the report on glass we find the jury saying, "We see, and see it with satisfaction, that the foreigners are making rapid advances, and are bringing their intelligence and their taste into competition with us . . . . it becomes our duty as well as our interest not to be backward in the struggle . . . . On behalf of that art, therefore, which is under our consideration, we claim the exercise of increased energy and science." Even with regard to our cutlery, we are told by the jury "that it would be untrue and unfair" not to state "that we have in certain branches of the manufacture some formidable rivals." Still more surprised were we, in hardware, to

* We are apt to be led into the question of competition, with which the argument has, in reality, little to do. If it be true, that a knowledge of natural forces aids production, then is it of advantage to the producer to acquire that knowledge; and this would be the case, even if there were no industrial competition in the world.

find "Austria, the States of the Zollverein, and Belgium, affording ample proofs of activity; the first-named country, in particular, exhibiting remarkable productive vigour." But why tire you with more quotations, when your every-day experience shows the increasing vigour of foreign industrial competition? When, therefore, we see competition thus pressing upon us on all sides, is it a sufficient reply to my argument to say, that because on the whole England is yet in advance, she is not to increase her rate of progress? or is it wise to go on nursing ourselves in national vanity, and in our isolation refuse to look at the causes which produce the rapid strides of industrial progress in other parts of the world? What these causes are I have endeavoured to explain, and the nature of the evidence has been laid before you. I do not doubt that you will properly appreciate its value; and if you arrive at the same conclusions as myself, you must be satisfied that it would be unwise further to delay the instruction of our industrial population, and will not, therefore, be surprised that I conclude with a warning quotation from Martial* :

> "Old Priam's age or Nestor's may be out,
> And thou, O *Taurus*, still go on in doubt;
> Come, then; how long such wavering shall we see?
> Thou may'st doubt on; but then thou'llt nothing be."

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* F. Lewis' translation of—

> . . . . . .
> Et non decernis *Taure*, quid esse velis,
> *Peleos* et *Priami* transit, vel *Nestoris* ætas,
> Et serum fuerat jam tibi desinere.—
> Eja, age, rumpe moras, quo te spectabimus usque?
> Dum quid sis dubitas, potes esse nihil.—*Mart.*

Appendix A.

Trade Institute of Berlin.*

This institution, as stated in the Lecture, has undergone various modifications in its constitution, and it may be desirable briefly to refer to them. It was founded in 1821, chiefly at the instigation of Von Beuth, who remained Director of it, and the Trade schools in connexion, up to 1845. An account of the principles upon which it was established is published in the "*Verhandlungen des Gewerb-Vereins in Berlin, Bd.* I. *s.* 142." The original aim seems to have been to communicate directly practical instruction by means of large workshops for metal-working, carpentry, modelling, &c., the instruction in science being confined to that which appeared necessary for actual tradesmen. The accommodation in the workshops being limited, the maximum number of students was 90, each of the 3 classes having 30; although, practically, 40 were received, because it was found that about 10 were unfit for the instruction given, and were removed after trial. This removal was the more easy, as not only was the instruction gratuitous, but actual material support was given to the pupils by the State. The three classes into which the Institution was divided comprised the following subjects:—

Under class	Physics. Chemistry. Drawing. Mathematics and arithmetic.
Higher class	A second course of the same subjects, treated more fully.
"Supreme" class	Technology of various kinds, applied to the special trades—workshop practice.

The following are the numbers who passed through and obtained certificates of merit from the three classes in the first twenty-five years of their existence, viz., 1821–1846:—

	No. of pupils.	Certificates of merit.
Class I., or lower class	800	140
Class II., or higher class	556	380
Class III., or supreme class	534	

If we analyze the occupations of the 520 recipients of certificates, it will be seen that they were nearly all tradesmen, the analysis being as follows:—

210	Mechanics and mill makers.
91	No fixed occupations.
64	Carpenters.
60	Bleachers, dyers, chemists, &c.
46	Builders.
17	Furniture makers.
13	Metal workers, engravers, &c.
10	Weavers.
5	Goldsmiths and tinplate workers.
3	Potters.
1	Cooper.

In 1845 Von Beuth ceased to be Director, and was succeeded by Pommerasche until 1848, and on his cessation there were two temporary Directors, until the appointment of the present Director Drückenmüller, in October 1849. Under this last Director great changes, both in the staff of professors and plan of the institution, have been made. These consisted in giving more of a collegiate and less of a school character to the Institution, the class of students being changed from that of tradesmen to managers of works and factories. The workshops, although still

* I am indebted to His Excellency Von Beuth and Privy Councillor Schubarth, as well as to Director Drückenmüller, for much information concerning this institution.

kept up at great expense, are not thought to be so essential to the instruction of the pupils as under the old system. The following are the present professors:—

Mathematics	Wölff.
Physics	Dove.
Chemistry	Rammelsberg.
Technology	Magnus.
Machinery	Wiebe and Fink.
Architecture	Löhde and Manger.
Free drawing	Freiberg.
Linear drawing	Pohlke.
Modelling	Kiss.
Design	Boettlicher.

The workshops are large and commodious, and well supplied with tools, and are under the management of one Director and ten experienced workmen; the "mechanics" attend them in the third year. In the first quarter, modelling in wood is taught; in the second, castings which may be made to the extent of between 3 and 4 tons in weight, the metal used being bronze or brass. During the rest of the time the pupil is engaged in the workshop making tools, turning lathes, and any special machinery ordered by Government. When any new machine of promise to technology is invented in foreign countries it is bought by Government, then sent to this Institution to be drawn and modelled, and is afterwards presented to a manufacturer, with the view of introducing it to the trade. The models for the museum are made in the workshop, according to scale, and accurate in detail; but they do not appear to be well arranged, and have no descriptive labels for the use of the public. In addition to the large workshops, there is a small one for carving, embossing, and inlaying metals; but it is not used directly for the instruction of the pupils; another workshop, however, for modelling in clay, plaster, &c., is in active operation. The budget for 1852 may be considered interesting, as it shows the manner in which the expenditure is divided.

	Thalers.	Subject-amounts. Thalers.
A. *Executive Staff*:—		
Drückenmüller, the Director, in addition to a free house	1,800	
Fickerman (Sub-director?)	800	
Wedding, librarian, &c.	400	
Assistant librarian and secretary	730	
Patskow, the porter	216	
Hoffman, servant and messenger	208	
Executive expenditure		4,154
B. *Professional Staff*:—		
Wölff - Mathematics	1,700	
Dove - Physics	600	
Rammelsberg - Chemistry	1,600	
Magnus - Technology	500	
Manger - Architecture	1,400	
Lohde - Idem, and architectural drawing	1,000	
First professor of machinery	1,400	
Wiebe - (second professor)	1,200	
Freiberg - Assistant professor (machine drawing)	600	
Kiss - Modelling	700	
Boettlicher - Design	500	
Expenditure on professors		11,200
C. *House Expenses*:—		
Heating, lighting, repairs, &c.	2,025	2,025
Carried forward		17,379

	Thalers.	Subject-amounts. Thalers.
Brought forward - - -	- - -	17,379
D. *Workshops, &c.:—*		
The Directors and workmen in the workshops -	5,130	
Material for the workshops - - -	1,570	
Allowance for laboratory material, &c. (actually 800)	600	
Models, apparatus, &c. (actually (1,400) - -	1,200	
Library books - - - - - -	1,500	
Workshop, &c., expenditure - -	- - -	10,000
E. *Money to Students, &c.:—*		
Money given to poor students for scientific journeys, &c. - - - - - -	17,100	17,100
F. *Miscellaneous:—*		
Miscellaneous expenses, as medals, certificates, &c.	321	321
		44,800

SUMMARY.

	Thalers.
Executive and professional staff - -	15,354
House expenses - - - - - -	2,025
Workshops, laboratory, library, models -	10,000
Students exhibitions and scientific journies	17,100
Medals, certificates, &c. - - -	321
	44,800

APPENDIX B.

POLYTECHNIC SCHOOL OF SAXONY.

A list of the professors and teachers in the Technical School of Dresden* may be of interest, as showing the division of subjects taught in similar schools. They are as follows:—

Hülsse (Director). Mechanical technology and national economy.
Schubert - Roads, railways, bridges, harbours, building, higher machinery, astronomy, projects for machines and building.
Schlömilch Analytical geometry, differential and integral calculus, higher mechanics.
Stein - Technical chemistry and laboratory work.
Löwe - - German in the upper classes.
Heine - Architecture and architectural drawing.
Hughes - English.
Geinitz - Geognosy, geology, mineralogy, zoology, botany.
Lösche - Experimental physics, higher physics, theoretical chemistry.
Puschner - Free and ornamental drawing.
Wenzel - Modelling in clay, composition of ornaments, &c.
Leclerc - French.
Tröger - Surveying in field, plan and chart drawing.
Fort, C. - Book-keeping and mercantile knowledge.
Kuschel - Mathematics.
Wahoda - German, political economy.
Erler - Laws of projection, perspective and machinery drawing.

* I have to express my obligation to Director Hülsse and Professor Stein for much information regarding the schools of Saxony.

Fort, O. - Mathematics and mechanics.
Hackel - Laws of machinery, mills, projects for machines, geometrical drawing.
Nagel - Higher geodesy, practical surveying, plans and geometrical drawing.
Röder - Modelling in wood.

Building School.

Hülsse (Director).
Arndt - Architecture, architectural drawing, projects for buildings.
Kuschel - Mathematics, statics, dynamics.
Puschner - Free and ornamental drawing.
Wahoda - German.
Erler - Projection, perspective, architectural drawing.
Hackel - Physical science.

It has been mentioned in the body of the Lecture, that the expenses of this school are much lower than those of the Trade Institute at Berlin, and the following is its balance sheet:—

Expenditure.	Thalers.	Receipts.	Thalers.
Teachers' salaries - -	13,640	State grant - - -	14,000*
Excursions for students -	160	Students fees - - -	3,100
Library - - -	700	Rent of house let to Director -	100
Materials for drawing and modelling - - -	150		
Museum and collections -	750		
Laboratory expenses -	300		
Heating and lighting - -	600		
Repairs - - -	500		
Domestics, &c. - -	400		
	17,200		17,200

Elementary Knowledge required by Pupils.

The following conditions for entrance are given as an example of the elementary knowledge which each student must possess before being admitted into a German Polytechnic school:—

General Conditions.—The student's age must be 15. He must have been vaccinated and confirmed, and be well grounded in the following subjects:—

A. *Arithmetic*, especially in raising powers and extracting roots, both of whole numbers and fractions; proportion; the fundamental rules of algebra, to equations of the first degree. B. *Plane Geometry*. C. *Natural History*, including a knowledge of indigenous families of plants and animals. D. *Geography and History*; the principal laws of mathematical and political geography, and the chief events in the progress of nations. F. *German*, so far as to show a readiness in expressing thoughts both orally and by writing. G. *Geometrical Drawing*, so as to show a ready use of drawing instruments, and their application to making constructions both by straight and curved lines. H. *Experimental Physics and Mineralogy*; an elementary knowledge in these is recommended previous to entering the preparatory division of the school, but is not an absolute condition for reception into it.

Examination of Candidates for the Service of the State.

Before the State grants employment to surveyors, engineers, mechanists or architects, and builders, the candidates must prove their qualifications by an examination before a Special Commission; and as this system is more or less pursued in all German States, the Saxon regulations may be quoted by way of general illustration. The general conditions are;—

1. The candidate must possess a certificate of his qualifications from one of the Technical schools.
2. He must show that he has been actually engaged for three years in the full practice of his profession.

These conditions being satisfied, he is subjected—1st. To an examination in the science and art of his profession. 2d. As to his powers of applying that science and

* The State grant usually amounts to 15,000 thalers.

art to the especial practical objects to be submitted to him. The knowledge required for the four chief Government employments above alluded to is as follows:—

For the Office of Surveyor.

Higher analysis.	Theoretical and practical geodesy.
Analytical mechanics.	Plan drawing.
Higher physics.	Astronomy.

These subjects include strict examinations in the higher analysis and mechanics; in theoretical astronomy, especially as to the determination of true and apparent time in given places, in the determination of the meridian and latitude of a place, and of the difference in longitude between two given places; trigonometrical surveying; chart and plan drawing; the theory and use of surveying instruments, as the barometer, levels, theodolites, circumferentor, plane table, compass, alidade, &c.

For the Office of Civil Engineer.

Higher analysis.	Geognosy and geology.
Analytical mechanics.	Roads, railways, hydraulic works, and plans for bridges, canals, railways, roads, &c.
Higher physics.	
Theoretical and practical geodesy.	

The examinations enter thoroughly into higher analysis and mechanics; mineralogy and geology; building materials; the theory and practice of roads and railways; the theory and practice of hydraulics and of foundations; the principles and practice of bridges, &c.

For the Office of Mechanist.

Higher analysis.	Motive powers.
Analytical mechanics.	Mechanical technology.
Higher physics.	Projects for machines.

The examination refers to an especial knowledge of the theory and construction of steam-engines; of the construction of mills; and of mechanical technology generally.

For the Office of Architect or Builder.

Higher analysis.	The history and æsthetics of architecture.
Analytical mechanics.	Architectural plans and projects.
Higher physics.	

In the examinations higher analysis and mechanics are used in reference to architecture generally, to building materials, plans, and construction of public buildings, their heating, lighting, ventilation, &c.

Appendix C.

Polytechnic School of Vienna.*

It has been mentioned in the Lecture that the technical part of this school contains 1,637 pupils, who are divided as follows:—

	Preparatory division.	Technical division.	Commercial division.	Total.
Matriculated students - -	419	870	95	1,384
Unmatriculated students - - -	—	222	31	253
	419	1,092	126	1,637

* My information regarding the schools of Austria has been derived chiefly from Chevalier de Burg, the late Director of the Central School; from Dr. Redlenbacher, the Professor of Chemistry in the University of Vienna; and from the obliging attention of the officials of the school, who placed their books and documents at my disposal.

In addition to the general technical department, there is one for drawing, which is attended as follows :---

	Week days.	Sundays.
Preparatory drawing -	184	500
Manufacturing drawing -	86	90
Drawing for metal work - -	76	112
Machine drawing - - - -	14	29
	360	731

The other subjects, taught in the Sunday schools, and attended by 650 students, have already been given. Of all classes of students, therefore, there are 3,378.

The public and lecture collections of the school are efficient, and consist of the following subjects :—

1. Raw materials and products.
2. Cabinet of mechanical models.
3. Cabinet of physical apparatus.
4. Collection of chemical products and preparations.
5. Cabinet of mathematical instruments.
6. Architectural collection.
7. Mineralogical and geological collections.
8. Trade collection of finished manufactures.
9. Agricultural collection.
10. The technical cabinet of the Emperor Ferdinand.

Appendix D.

Bavaria.*

The scheme of instruction in the Polytechnic School of Munich has been given in the body of the Lecture; and it may be useful to append that of the two other head schools of Bavaria.

Scheme of Instruction at Nurnberg.†

Course I.			Course II.			Course III.		
Summer.	Winter.	—	Summer.	Winter.	—	Summer.	Winter.	—
Hrs.	Hrs.		Hrs.	Hrs.		Hrs.	Hrs.	
4	4	Trigonometry.	5	5	Theory of equations; differential and integral calculus.	2	2	Higher mathematics.
2	4	Analytical geometry.				5	5	Mechanics.
2	2	Equations.				3	3	Machinery.
6	6	Descriptive geometry.	5	5	Mechanics.	8	8	Analytical chemistry.
3	-	Practical geometry.	3	3	Physics.	12	12	Architectural and machine drawing.
5	5	Physics.	8	8	Chemistry.			
8	8	Drawing.	12	12	Drawing.			

* For the information regarding the schools of Bavaria I am chiefly indebted to Professor Schaffhaeutl, the present Royal Commissioner of the Central School; to Dr. Alexander, the Director and Ministerial Referee; and to much courteous attention at the Ministry of Trade.

† Besides the above lectures practical instruction is given in workshops, the foundry, and laboratory.

Scheme of Instruction at Augsburg.

Course I.	Course II.	Course III.
Analysis; trigonometry; analytical and descriptive geometry. Physics. Drawing (architectural, machine, figure, manufacturing).	Differential and integral calculus. Analytical mechanics. Surveying. Technical chemistry. Architecture. Drawing (architectural, machine, plan, figure, manufacturing).	Applied mechanics. Analytical chemistry. Architecture. Machinery. Drawing (architectural, machine, figure). Mechanical workshops.

Building School at Munich.

As there is no example of a building school given in the body of the Lecture, I describe the general features of this school somewhat in detail, expressing my obligations to the Principal and to Professor Haindl for all the information which I possess regarding it. The school was established in 1823, and is chiefly intended for workmen, such as carpenters and masons who intend to be, or are, engaged in building; but it is also numerously attended by masters themselves. Persons of all nations are admitted, provided they possess the requisite elementary knowledge. In order to enable men engaged in the active pursuits of their trades to enter the school, the session is between the 11th November and the 19th March, a period when building is scarcely carried on in Germany. There is a very good collection of models made by the students themselves, the workshops being open from 8 A.M. until late in the evening. The school has nine professors, and had last year 143 pupils, but it has not yet recovered from the political convulsions of 1848, previous to which year it had 200 students, the number of whom diminished immediately to 55, in consequence of the disturbed state of the country. The school is conducted economically, the fee for the 4½ months course being only 13*s.*; the total cost of the school, which is defrayed by a local grant, being a little less than 200*l.* The subjects are not yet divided into special courses, the pupil being allowed to choose those which he desires to study; they are as follows:—

1. Free and linear drawing.
2. Plain and ornamental writing.
3. Arithmetic and the elements of geometry for beginners.
4. Plane and solid geometry and mechanics, with applied arithmetic for more advanced students.
5. Descriptive geometry.
6. Laws of building materials.
7. Heating, ventilation, &c.
8. Stone-cutting, and practice in modelling with plaster.
9. Wood construction, consisting in drawing, projection, and modelling in wood.
10. Embossing ornaments, &c., in clay and plaster.
11. Laws of projection, including practice in planning for given subjects.
12. Contracting for the above.
13. The elements of general architecture.
14. Building laws and police.

The school has a fund amounting to 10,000 florins, the yearly interest of which is devoted to sending one or two of the most promising pupils to foreign countries, to cull their experience, and bring it back to their "fatherland." The principal countries which seem to send workmen to this school to be educated are Hungary, Moldavia, Denmark, and Switzerland. The additional means of instruction in the school, besides those already mentioned, are,—

1. A valuable library, consisting chiefly of works on building, and of architectural plates of ancient and modern times.
2. A collection of 1,500 subjects for drawing.
3. A collection of subjects for modelling.
4. From 180 to 200 specimens of stone work.
5. From 70 to 80 subjects for the use of carpenters.
6. Workshops for modelling, stone-cutting, carpentry, &c.

Appendix E.

Ecole Centrale des Arts et Manufactures.

This institution is so important in itself, and so interesting from its great commercial success, as a private undertaking in France, where similar schools are always supported by Government, that it has been referred to at length in the Lecture, and now some further details are inserted concerning it. We must accept the facts, that the students are only limited to 300 by the size of the building, and that manufacturers eagerly demand the certificated pupils of the institution, as convincing proofs of its importance to the industry of France. There is now appended, (1) a list of the distinguished professors of the school; (2) its general rules; and (3) the conditions of admission, or amount of elementary knowledge possessed by a candidate before he is accepted as a pupil.

Personnel de l'Ecole.—Année 1851–1852.

M. Lavallée, Directeur de l'Ecole.
M. Empaytaz, ancien élève de l'Ecole Polytechnique, Directeur des Etudes.

Professeurs, Membres du Conseil des Etudes.

Dumas, C.	(1829) Sénateur, Membre de l'Académie des Sciences	Cours de Chimie générale.
Olivier, O.	(1829) Prof. au Conserv. des Arts et Mét., *Président du Conseil des Etudes*	Géométrie descriptive.
Péclet, O.	(1829) anc. Inspect^{r} général de l'Université	Physique industrielle.
Ferry	(1830) Ingénieur civil	Métallurgie du fer et Technologie mécanique.
Perdonnet	(1831) l'un des Administrateurs-Directeurs du chemin de fer de Strasbourg. *Vice-Président du Conseil des Etudes*	Chemins de fer.
Mary, O.	(1833) Inspect. divis. des Ponts et Chaussées	Constructions et Travaux publics, Architecture.
Payen, O.	(1835) Membre de l'Académie des Sciences, Prof. au Conserv. des Arts et Métiers	Essais commerciaux; Chimie industrielle et Chimie agricole.
Belanger	(1836) Ingén. en chef, Profes. à l'Ecole des Ponts et Chaussées et à l'Ecole Polytechn.	Mécanique industrielle.

Professeurs.

Peligot	(1835) Membre de l'Académie des Sciences, Prof. au Conservatoire des Arts et Métiers	Analyse chimique.
Thomas	(1838) ancien élève de l'Ecole Centrale, Ingénieur civil	Machines à vapeur.
Burat (Amédée),	(1841), Ingénieur civil	Géognosie et exploitation des mines.
Masson	(1841) Agrégé de la Faculté des Sciences	Physique générale.
Martelet	(1841) ancien élève de l'Ecole Polytechn.	Analyse géométrique et Mécanique générale.
Doyère	(1845) Professeur à l'Institut national agronomique de Versailles	Physiologie et Histoire naturelle appliquée à l'Industrie.
Faure	(1851) ancien élève de l'Ecole Centrale, Ingénieur civil	Transformations du mouvement.
Polonceau	(1851) ancien élève de l'Ecole Centrale, Ingénieur civil	Construction et établissement des machines.

Professeurs-Adjoints.

Cahours	Examinateur de sortie à l'Ecole Polytechn.	Chimie générale.
Sonnet	Inspecteur de l'Académie de Paris	Mécanique industrielle.

Examinateur d'Admission à Paris pour 1852.

Sonnet - *Déjà nommé.*

Quelques leçons de Technologie spéciale sont faites par:

Alcan - - Ingénieur, ancien élève de l'Ecole Centrale, chargé de leçons sur les Matières textiles (préparation, filature et tissage de la soie, du coton, de la laine, etc.)

Salvetat - - Ingénieur civil, ancien élève de l'Ecole Centrale, Chimiste à la Manufacture nationale de Sèvres, chargé des leçons sur la Poterie.

Chefs des travaux Chimiques.

Favre - - Professeur agrégé à la Faculté de Médecine de Paris.
Rigout - - Préparateur de Chimie organique à la Faculté de Médecine de Paris.

Chefs des travaux Graphiques.

Thumeloup - Architecte.
Tronquoy - Maître de Dessin à l'Ecole Polytechnique.
Robert - - Adjoint.

Répétiteurs.

Daniel - -	Licencié ès sciences physiques - -	Physique générale.
Cahours -	*Déjà nommé* - - - -	Chimie générale.
Fernique -	Professeur de Mathématiques - -	Géométrie descriptive.
Priestley -	Ingénieur, ancien élève de l'Ecole Centrale	Analyse géométrique et Mécanique générale.
Descloiseaux	Ancien élève de l'Ecole des Mines -	Géognosie et exploitation des mines.
Faure - -	*Déjà nommé* - - - -	Métallurgie du fer.
Poinsot - -	Chef des travaux chimiques au Conservatoire des Arts et Métiers - -	Chimie industrielle.
Bénard - -	Ingénieur, ancien élève de l'Ecole Centrale	Constructions et travaux publics.
Sonnet - -	*Déjà nommé* - - - -	Mécanique industrielle.
Thomas -	*Déjà nommé* - - - -	Physique industrielle.
Cornet - -	Ingénieur, ancien élève de l'Ecole Centrale	Chemins de fer.
Debonnefoy -	Ingénieur, ancien élève de l'Ecole Centrale	Construction des machines.

Préparateurs.

Jacquelain - Licencié ès sciences physiques, Préparateur des cours de Chimie.
Daniel - - *Déjà nommé*, Preparateur des cours de Physique.
Leconte - Aide-Préparateur de Chimie.

Service d'Administration.

Fabre - - Caissier, chargé de la conservation du matériel.
Latruffe - Commis. d'ordre.
Valette - Commis.

Bibliothèque.

Bibliothécaire.
Perin - - Sous-Bibliothécaire.

Service de surveillance et de discipline.

Rameau - }
Cance - } Inspecteurs des élèves.
Poujol - }
Guillot - }

Médécin de l'Ecole.

Cazenave fils, Professeur agrégé de la Faculté de Médecine de Paris, Médecin de l'Hôpital Saint-Louis.

The following extracts from the Statutes, in addition to the remarks in the Lecture, will sufficiently indicate the general character of the school, and of the subjects taught in it:—

STATUTS GÉNÉRAUX DE L'ECOLE.

§ I. *But de l'Ecole.*

1°. L'Ecole Centrale est destinée spécialement à former des ingénieurs civils, des directeurs d'usines, des chefs de fabriques et de manufactures; à alimenter l'industrie d'hommes capables d'apporter dans la direction de ses établissements et de ses grands travaux les lumières que fournissent les sciences physiques et mathématiques, non-seulement étudiées dans leurs doctrines les plus importantes et les plus générales, mais considérées surtout au point de vue de leur application pratique.

§ II. *Institution de l'Ecole.*

2°. L'autorité supérieure dans l'Ecole appartient à un directeur et à un Conseil des études, qui délègue une partie de ses pouvoirs à un directeur des études.

3°. Le directeur de l'Ecole demeure dans l'établissement. Il est chargé de l'administration et de la correspondance. Il règle tout ce qui est relatif aux recettes et aux dépenses de l'établissement. Il veille à l'exécution des statuts et règlements. Le directeur seul prend les engagements pour les divers emplois; mais il ne peut choisir le directeur des études, les professeurs et les répétiteurs que sur la présentation du Conseil des études.

4°. Le Conseil des études se compose de neuf professeurs et du directeur des études. Il se réunit au moins une fois par mois, sur la convocation de son président. Il a dans ses attributions tout ce qui est relatif à l'enseignement, aux études et aux travaux des élèves.

Le Conseil des études arrête le règlement relatif à l'ensoignement et à la discipline de l'Ecole. Il peut le modifier suivant les circonstances.

Le Conseil admet ou rejette les candidats d'après les procès-verbaux de leurs examens. Il prononce à la fin de chaque année sur l'aptitude des élèves soit à passer dans une division supérieure, soit à recevoir le diplôme d'ingénieur ou le certificat de capacité.

Il présente à la nomination du directeur de l'Ecole les candidats pour la direction des études et pour les chaires vacantes. Il désigne chaque année les répétiteurs et l'examinateur pour les aspirants à l'Ecole.

Les professeurs sont choisis, autant que possible, parmi les hommes joignant à la théorie une connaissance profonde de la pratique.

5°. Le Conseil des études, dans l'intervalle de ses séances, est représenté par un *conseil d'ordre*, composé du directeur des études et d'un professeur, au moins, désigné pour cette fonction. Le directeur de l'Ecole assiste à ses séances, qui ont lieu au moins une fois par semaine.

6°. Le directeur des études est chargé de l'exécution des décisions du Conseil des études. Il fait les ordres du jour nécessaires pour régler les études et pour maintenir la discipline dans l'Ecole.

7°. Les élèves peuvent réclamer par écrit auprès du Conseil des études ; mais même, dans ce cas, les règlements et ordres du jour sont obligatoires sans délai jusqu'à ce qu'ils aient été modifiés.

Tout élève en entrant à l'Ecole prend l'engagement de ne faire partie d'aucune réunion qui aurait pour but de s'opposer à l'exécution des décisions prises par le Conseil des études ou par les directeurs. Il promet de ne prendre part à aucune coalition tendant à imposer aux élèves les décisions ou les volontés d'une partie quelconque d'entre eux.

8°. L'Ecole ne reçoit que des élèves externes.*

9°. Les élèves ne portent pas d'uniforme. (Arrêté ministériel du 17 Octobre 1849, rapportant celui du 10 Mars 1848.)

§ III. *Enseignement.*

10°. La durée du cours complet d'instruction à l'Ecole Centrale est de trois ans.

L'enseignement se compose des cours, des interrogations journalières, des travaux graphiques, des manipulations de chimie, de coupe des pierres et de charpente, de physique et de mécanique, des constructions, des problèmes, projets et concours partiels, des examens généraux.

11°. Pendant les trois années d'étude, tous les cours sont obligatoires pour les élèves ; mais, à partir du milieu de la seconde année, les dessins, les manipulations et les projets se partagent en deux séries : l'une générale et l'autre relative à la spécialité à laquelle se destine chaque élève.

12°. Les spécialités sont au nombre de quatre, savoir :

1. Spécialité des mécaniciens. Construction et établissement des machines, arts mécaniques.
2. Spécialité des constructeurs. Construction des édifices, travaux publics, arts physiques : ponts, canaux, routes, chemins de fer ; architecture civile et industrielle ; chauffage, éclairage, salubrité des villes et des grands établissements.

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* Hors du temps que les élèves sont obligés chaque jour de passer dans l'établissement, ils doivent se livrer chez eux à l'étude des notes qu'ils ont recueillies dans les cours, à la rédaction des Rapports, des Mémoires qui leur sont demandés, travail qui exige le calme de la retraite ; et lorsque leur tâche est accomplie, ils emploient leurs courts loisirs à visiter des ateliers et des usines dont les travaux sont en rapport avec les diverses branches de l'enseignement de l'Ecole. Mais il est des familles qui craignent avec raison d'abandonner à eux-mêmes leurs fils, trop jeunes encore pour user avec sagesse de la liberté ; le directeur de l'Ecole peut satisfaire à leur juste sollicitude en leur recommandant avec confiance une institution située dans le voisinage, et dont la destination spéciale est tout à la fois de préparer les jeunes gens qui aspirent à entrer à l'Ecole, et de recevoir en pension ceux qui en suivent les cours.

3. Spécialité des métallurgistes. Exploitation des mines. Métallurgie.
4. Spécialité des Chimistes. Chimie. *Chimie minérale* : poteries, porcelaine, verrerie, minium, produits chimiques en général, acide sulfurique, acide hydrochlorique, soude, chlorure de chaux, aluns, sulfates de fer et de cuivre, chromates, salpètre ; art de l'essayeur ; affinage des métaux précieux, etc., etc. *Chimie organique, Arts agricoles* : teinture, couleurs, vernis, acide pyroligneux, vinaigres, acétates, céruse, crèmes de tartre acide, tartrique, sucre de cannes et de betteraves, amidon, toiles peintes et papiers peints, distilleries, brasseries, huiles, graisses, cire, savons, tannerie, charbon animal, bleu de Prusse, gélatine, etc., etc.

Chaque élève de deuxième année doit déclarer, à la fin du premier semestre, quelle est, parmi ces spécialités, celle à laquelle il se destine.

13°. Des interrogations journalières sont faites par les professeurs et par des répétiteurs ; les notes des examens restent en dépôt à la direction des études, où se fait le classement des élèves à interroger.

14°. Les travaux graphiques se composent de dessin architectural, de lavis, d'épures à la règle, au compas et à l'échelle, et de croquis tracés à main levée et cotés, relatifs à tous les cours.

Une importance extrême est attachée à ces travaux, le dessin étant pour les ingénieurs un langage indispensable, et dont l'emploi doit leur être très-familier.

15°. Les manipulations de chimie sont assez nombreuses pour donner aux élèves une instruction positive dans cette science.

Les élèves de première année manipulent une fois par semaine dans les laboratoires, et, en outre, exécutent les expériences de physique les plus essentielles. Ils opèrent sous les yeux des répétiteurs attachés aux cours.

A partir du deuxième semestre de la deuxième année d'études, et pendant toute la troisième année, les élèves qui appartiennent aux spécialités *Chimie industrielle* ou *Métallurgie*, complètent leur instruction chimique en manipulant à tour de rôle dans les laboratoires d'analyse.

Les manipulations de 2^{e} et 3^{e} années sont surveillées par le chef des travaux chimiques, sous la direction du professeur d'analyse chimique.

16°. Enfin, on met à la disposition des élèves tous les matériaux nécessaires à la construction de quelques appareils d'art. Ils les établissent eux-mêmes, d'après les dessins qui leur sont donnés ou d'après les projets qu'ils ont étudiés.

17°. Pour rendre complet le système d'enseignement, on a joint aux éléments précédents des problèmes à résoudre pendant la première année. A partir de la seconde, les élèves sont chargés de dresser des projets de plus en plus compliqués qui les familiarisent d'abord avec les détails des constructions industrielles, et plus tard avec les dispositions d'ensemble qui sont les plus convenables dans chaque classe d'usines. Ces projets sont examinés par les professeurs dans des conférences.

18°. Indépendamment des interrogations faites pendant la durée des cours, les élèves subissent à la fin de chaque année scolaire des examens généraux sur toutes les branches de l'enseignement.

Les résultats de ces examens, combinés avec ceux des interrogations qui ont lieu dans le courant de l'année, et en outre avec les notes prises pendant les manipulations et les expériences, celles qui sont données aux dessins et projets exécutés par l'élève, et enfin celles qui se rapportent à la conduite, forment un ensemble d'après lequel le Conseil des études prononce sur le passage dans une division supérieure des élèves de 1re et 2^{e} année, suivant un classement par ordre de mérite, et sur l'aptitude des élèves de 3^{e} année à concourir pour le diplôme d'ingénieur.

19°. Les élèves ont à leur disposition une bibliothèque composée des ouvrages qui peuvent leur être nécessaires pour y faire les recherches relatives à l'exécution de leurs projets. La bibliothèque est ouverte le soir jusqu'à neuf heures pour tous les élèves de l'Ecole.

20°. Les cours de l'Ecole commencent, chaque année, le 10 Novembre pour la 1re année, et le 2 Novembre pour la 2^{e} et la 3^{e} année. Ils finissent dans le courant du mois de Juillet.

Les examens généraux ont lieu à la fin de chaque cours et sont tous terminés du 10 au 20 Août.

Les vacances commencent après les examens généraux.

§ IV. *Diplômes et certificats de capacité.*

21°. Les élèves de 3^{e} année sont admis à concourir pour l'obtention du diplôme, par décision du Conseil des études, conformément aux règles tracées par l'art. 18.

22°. Les élèves entrent en concours le 25 Juin.

23°. Le programme d'un projet est rédigé pour chaque spécialité. Les élèves ont trente-cinq jours pour en exécuter les dessins, dans l'intérieur de l'Ecole, et rédiger le

Mémoire à l'appui. Enfin ils soutiennent un examen oral sur leur projet, qu'ils sont obligés de développer et de défendre en présence d'un jury composé de cinq professeurs au moins.

24°. Le concours terminé, les professeurs se réunissent en conseil et statuent sur les diplômes d'ingénieur et les certificats qu'il y a leur d'accorder.

25°. Le diplôme d'*ingénieur civil* est accordé aux élèves qui ont satisfait aux épreuves exigées pendant les trois années d'Ecole, et surtout à celles du concours qui termine les études. Le *certificat de capacité* est accordé à ceux qui n'ont satisfait qu'à certaines de ces épreuves.

26°. Tout élève admis au concours qui en a subi toutes les épreuves, et qui a échoué, peut s'y représenter les années suivantes aux époques fixées par le Conseil des études, en se soumettant aux autres règlements de l'Ecole, et sans être obligé de redoubler la troisième année.

27°. L'Ecole ne reconnaît comme anciens élèves que ceux qui ont obtenu le diplôme d'ingénieur ou le certificat de capacité. Il est interdit au directeur de l'Ecole et aux professeurs d'accorder aux autres élèves aucune espèce de certificat spécial.

28°, Tous les projets et Mémoires de concours appartiennent à l'Ecole et sont déposés à la bibliothèque pour servir à l'enseignement.

29°. Les élèves de la deuxième année doivent assister au concours. Le public peut y être admis.

Frequent allusions have been made in the Lecture to the necessity of demanding a sufficient amount of elementary knowledge, on the part of the pupil, before he is received into an industrial college. The demand has the double benefit of enabling the professors to devote their whole time to the industrial applications of science and art, and also of giving an impulse to schools of general education, which are thus converted into allies of, instead of being made antagonists to, schools of industry. The following conditions are, therefore, given in illustration of the elementary knowledge requisite for admission, although it is in this case chiefly confined to the mathematical sciences :—

PROGRAMME DES CONNAISSANCES EXIGÉES POUR L'ADMISSION À L'ECOLE CENTRALE.

Arithmétique.

Nombres entiers.—Les quatre opérations principales sur les nombres entiers.—Emploi du complément arithmétique pour substituer l'addition à la soustraction.—Un produit est indépendant de l'ordre de ses facteurs et de la manière dont ils peuvent être groupés s'il y en a plus de trois. Exemple : $a.b.c.d.e.f = e.b\,(d.a.)\,(f.c)$. Conséquences de ce principe quand un ou plusieurs facteurs sont terminés par des zéros.—Le produit de deux nombres entiers a autant de chiffres qu'il y en a dans les deux facteurs ensemble ou un de moins.

Décomposition d'un nombre en ses facteurs premiers. — Le produit de plusieurs nombres premiers n'est divisible par aucun autre nombre premier.—Caractères de la divisibilité d'un nombre par 2, 3, 5, 9, et application dite *preuve par* 9.—Recherche du plus grand commun diviseur de deux nombres et en général de plusieurs nombres.—Détermination du plus petit multiple de plusieurs nombres.

Fractions ordinaires.—Définition des fractions.—Définitions de la multiplication et de la division, applicables aussi bien quand le multiplicateur et le quotient sont fractionnaires que lorsqu'ils sont entiers.—Divers usages de la division.

Toute fraction multipliée par son dénominateur produit le numérateur.—Le quotient *complet* de la division d'un nombre entier par un autre est une fraction qui a pour numérateur le dividende et pour dénominateur le diviseur ; l'opération appelée division des nombres entiers donne la partie *entière* du quotient.—On ne change pas la valeur d'une fraction si on multiplie ou divise ses deux termes par un même nombre.—Réduire une fraction à sa plus simple expression. — Amener plusieurs fractions au plus simple dénominateur commun.—Addition et soustraction des fractions.

Produit de plusieurs fractions. Il est indépendant de l'ordre des facteurs.—Division d'un nombre quelconque par une fraction. On ne change pas le quotient en multipliant ou divisant le dividende et le diviseur par un même nombre entier ou fractionnaire.—La multiplication et la division des fractions se ramenant à des multiplications sur des nombres entiers, les élèves doivent être exercés à supprimer les facteurs communs aux deux termes de la fraction résultante avant d'effectuer les multiplications.

Si plusieurs fractions sont égales et qu'on les ajoute terme à terme, c'est-à-dire qu'on prenne pour numérateur la somme des numérateurs et pour dénominateur celle des dénominateurs, la nouvelle fraction est égale aux premières ; mais si celles-ci sont

inégales, la nouvelle fraction obtenue est comprise entre la plus petite et la plus grande des fractions primitives. Application de ce théorème au cas particulier d'une fraction et de l'unité sous la forme $\frac{m}{m}$. — Propriétés et calcul de la moyenne arithmétique de deux et en général de plusieurs nombres.

Fractions décimales.—Les quatre opérations principales sur les fractions décimales.

La division d'un nombre entier ou fractionnaire décimal par un autre se ramène toujours, par le déplacement des virgules décimales, au cas où le diviseur est un nombre entier terminé par un chiffre *autre que zéro.*

Transformation d'une fraction ordinaire en fraction décimale et réciproquement.—Notions principales sur les fractions périodiques.

Détermination du degré d'exactitude certaine du résultat d'une des quatre opérations principales, quand un ou plusieurs des nombres donnés ne sont qu'approximatifs à moins d'une demi-unité près de l'ordre de leur dernier chiffre.

Système métrique décimal. — Connaissance complète du système métrique décimal.

Les élèves doivent savoir tracer sur le tableau, sans l'aide d'aucune mesure, à moins d'un dixième près, la longueur d'un mètre, d'un ou de plusieurs décimètres, d'un ou de plusieurs centimètres.

Définitions de l'are, de l'hectare, du litre, du kilolitre, du gramme, du kilogramme, du tonneau de mille kilogrammes, tirées chacune immédiatement de la connaissance du mètre et de ses subdivisions.—Définition du franc.

Une quantité concrète étant rapportée à une unité quelconque du système métrique, trouver, par le simple déplacement de la virgule, l'expression de la même grandeur quand l'unité est prise parmi les multiples ou sous-multiples décimaux de la première, notamment quand le mètre carré et le mètre cube sont remplacés, comme unités, l'un par le décimètre carré, le centimètre carré..., l'autre par le décimètre cube, le centimètre cube..., et réciproquement.

Application des quatre opérations principales à des questions sur des quantités exprimées d'après le système métrique décimal.

Anciens nombres complexes.—Les quatre principales opérations sur les nombres complexes dans les cas les plus ordinaires.

Algèbre.

Les quatre règles sur les monômes, les polynômes et les fractions algébriques.

Résolution et discussion des problèmes déterminés du 1er *degré* à une ou plusieurs inconnues, en insistant sur la pratique du calcul.—Faire voir que les solutions négatives satisfont *algébriquement* aux équations d'où elles sont déduites, et indiquer par des exemples le parti qu'on en tire dans la résolution des problèmes.

Proportions.—Ce qu'on entend par deux quantités commensurables. L'expression la plus simple de leur rapport est donnée par deux nombres entiers premiers entre eux. Deux fractions abstraites ou affectant une même unité concrète sont dans ce cas.—On ne change pas un rapport en multipliant ses deux termes par un même nombre plus grand ou plus petit que 1.—Ce qu'on entend par le rapport approché (par exemple à un centième, à un millième près...) de deux quantités de même nature qui peuvent être commensurables ou incommensurables.

Toute proportion entre des quantités commensurables deux à deux peut être mise sous la forme $mA : nA :: mB : nB$, m et n étant deux nombres abstraits, A et B deux quantités de nature quelconque. On peut déduire de cette considération toutes les propriétés des proportions.

Deux quantités variables dépendant l'une de l'autre, qu'entend-on lorsqu'on dit que les valeurs de la première sont directement ou réciproquement proportionnelles aux valeurs correspondantes de la deuxième?—Règles de trois directe, inverse.

Si une quantité z varie en raison directe de certaines variables $p, q, \ldots$ et en raison inverse d'autres variables $t, u, \ldots$, faire voir qu'on a $z = k\frac{p \cdot q \cdots}{t \cdot u \cdots}$, en désignant par k un coefficient constant qui se détermine quand on connaît un système de valeurs simultanées $z', p', q' \ldots t', u' \ldots$ des variables.

Application : règle de trois composée.

Partage d'un nombre en parties proportionnelles deux à deux à des nombres entiers et fractionnaires donnés (procédé de la règle de société).

Etant connu le rapport d'une quantité à une autre, de celle-ci à une troisième, de la troisième à la quatrième, et ainsi de suite, trouver le rapport de la première à la quatrième.—Questions et procédés connus sous les noms de règles conjointe et d'arbitrage.

Extraction des racines carrée et cubique des nombres entiers ou fractionnaires avec un degré déterminé d'approximation. Si l'on opère sur un nombre entier ou décimal, à quel

caractère reconnaît-on que le résultat est exact à moins d'une demi unité près de l'ordre du dernier chiffre ?

Résolution et discussion des équations du 2e degré et des équations bi-carrées à une inconnue.—Problèmes à plusieurs inconnues qui par l'élimination se ramènent aux cas précédents.

Binôme de Newton, dans le cas de l'exposant entier positif, fondé sur la théorie des combinaisons.

Puissances et ravines des monômes.—Théorie des exposants négatifs ou fractionnaires.

Propriétés des logarithmes considérés comme exposants variables.—Usage des tables les plus simples.—Applications diverses en insistant, dans le cas de l'extraction des racines, sur la modification à faire subir à la caractéristique lorsqu'elle est négative.

Progressions par différence et par quotient.—Relations entre le premier terme, le dernier, la raison, le nombre des termes et leur somme.—Limite de la somme des termes d'une progression décroissante.—Insertion de moyens.—Questions principales d'intérêt composé, comprenant les annuités.

Notions sur l'homogénéité des équations algébriques entre des quantités concrètes.

Géométrie.

Mesures des droites, des arcs de même rayon, des angles à l'aide de celle des arcs ayant les sommets pour centres.

Propriétés des perpendiculaires, des obliques, des parallèles. On admet comme évident qu'une perpendiculaire et une oblique à une même droite se rencontrent.

Somme des angles d'un triangle et d'un polygone quelconque.

Condition de l'egalité des triangles et des figures rectilignes.—On distinguera pour les figures situées dans un même plan, l'égalité directe de l'égalité par renversement qui a lieu quand l'une des figures ne peut coïncider avec l'autre qu'en la détachant du plan et la retournant ; deux figures planes dont les points se correspondent symétriquement par rapport à un axe, sont dans ce dernier cas.

Lignes proportionnelles qui résultent de droites coupées par des parallèles.—Similitude (directe ou par renversement) des triangles et des figures planes rectilignes.—Bissectrice d'un angle intérieur ou extérieur d'un triangle.—Deux droites antiparallèles par rapport à un angle déterminent deux triangles semblables par renversement.

Propriétés du triangle rectangle.—Relation numérique entre les trois côtés d'un triangle quelconque et la projection d'un côté sur l'un des deux autres.—Autre relation entre les trois côtés et la ligne droite qui joint un sommet au milieu du côté opposé.

Tracé de la circonférence par trois points.—Tangente.—Conditions pour que deux circonférences soient l'une extérieure ou intérieure à l'autre, pour qu'elles se touchent ou se coupent ; propriété de la corde commune et de la ligne des centres.

Détermination du nombre de degrés d'un angle par celui des arcs que ses côtés déterminent sur une circonférence qu'ils rencontrent ou touchent.

Tangente à deux cercles.—Cercle tangent à une ou plusieurs droites.

Si une droite tourne dans un plan en passant par un point fixe et rencontrant une circonférence, les deux distances du point fixe aux intersections simultanées sont deux variables réciproquement proportionnelles.

Moyenne proportionnelle entre deux droites (divers procédés).—Partage d'une droite en moyenne et extrême raison. Trouver l'expression numérique de chaque partie, la ligne entière étant prise pour unité.

Trouver graphiquement la longueur d'une ligne exprimée algébriquement en fonction de lignes connues soit sans radicaux, soit avec des radicaux du 2e degré.

Propriétés principales du parallélogramme, du losange, du trapèze, des polygones réguliers. —Rapports des côtés du carré, de l'hexagone régulier, du triangle équilateral, du décagone régulier, au rayon du cercle circonscrit.

Calcul du rapport de la circonférence au diamètre.

Relation entre le nombre de degrés d'un arc, sa longueur et celle du rayon.

Calcul des aires des figures planes et rectilignes.—De l'aire du cercle, d'un secteur.—Rapport des aires des polygones semblables, de deux cercles, de deux secteurs.—Tracé des figures planes, leur réduction et leur amplification dans un rapport donné.—Echelles.

Propriétés d'une ou plusieurs droites perpendiculaires à un plan.—Mesure de l'inclinaison d'une droite par rapport à un plan.—Mesure de l'angle de deux plans.—Parallélisme des droites et des plans.—Propriétés principales des angles polyèdres.—Etant données les trois faces d'un angle trièdre, déterminer ses trois angles dièdres, et réciproquement....—Etant données deux faces et l'angle dièdre compris, déterminer la troisième face.—Lignes proportionnelles résultant de l'intersection de droites coupées par des plans parallèles.

Notions générales sur la similitude, comprenant comme cas particulier les figures planes.*

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* Un système de points M, N, P,...(formant soit des lignes, soit des surfaces, soit un ou plusieurs corps), etant situé d'une manière quelconque dans l'espace, si l'on prend un point

Propriétés principales des polyèdres les plus simples, du cylindre et du cône de révolution, de la sphère.—Trouver le rayon d'une sphère par une construction plane.

Somme des aires des faces latérales d'une prisme, déterminée par le périmètre de sa section droite et la longueur commune des arêtes latérales; application à la surface convexe d'un cylindre.—Surface convexe du cône droit, du cône tronqué, d'une calottte sphérique, d'une sphère.—Rapport des surfaces des corps semblables.

Volume des corps terminés par des plans.—Volume d'un prisme triangulaire à bases parallèles ou non, soit en fonction de l'aire de l'une des bases et des hauteurs relatives à cette base, soit en fonction de l'aire de la section droite et des longueurs des arêtes latérales.

Volume du cylindre droit, du cône, de la sphère, d'un segment sphérique en fonction de sa hauteur et du rayon de la sphère.

Rapport des volumes des corps semblables.

Dessin.

Etudes de dessin au trait et à la regle; études de dessin à main levée; études de lavis d'architecture. *

Observations.

Toutes les fois qu'il s'agira de démontrer l'égalité de deux rapports entre des quantités qui peuvent être incommensurables, on démontrera que leurs rapports approchés à un même degré d'approximation sont toujours égaux.

On préférera pour la géométrie curviligne les démonstrations par les infiniment petits ou par les limites.

Les élèves devront être exercés à traduire en nombres tous les théorèmes de la géométrie qui en sont susceptibles, et à en faire des applications.

Tout progrès à l'Ecole Centrale est impossible sans une bonne instruction préparatoire. C'est dans l'intérêt des jeunes gens qui s'y destinent qu'on publie le programme un peu développé des connaissances *indispensables*; mais pour ceux qui, avant leur entrée à l'Ecole, peuvent étendre leurs études au delà du strict nécessaire, le Conseil des études les engage à acquérir quelques notions sur les éléments de géométrie descriptive, sur ceux de la géométrie analytique, comprenant la trigonométrie rectiligne fondée sur la théorie des projections;† enfin sur les éléments de la physique et de la chimie. Il les engage aussi à donna tous leurs soins à l'art du dessin, dont l'ingénieur civil ne saurait se passer.

Le Conseil de l'Ecole a reconnu que beaucoup d'élèves manquaient en arrivant de l'habitude de prendre ces notes à l'amphithéâtre. Il invite les jeunes gens qui se préparent pour l'Ecole à prendre cette habitude de bonne heure, et il engage MM. les Professeurs des Ecoles préparatoires à surveiller cette partie de leur éducation.

S aussi quelconque (pouvant comme cas particulier être l'un de ceux du système); qu'on mène les droites SM, SN, SP,...et que sur ces droites, prolongées au besoin, on porte à partir du point S les distances SM′, SN′, SP′,...proportionnelles à SM, SN, SP,...et dirigées réspectivement dans le même sens; les points M′, N′, P′,...ainsi obtenus formeront un système *semblable* au système M, N, P, et *semblablement placé* par rapport au point S qui s'appelle *pôle commun de similitude*. Les points M′, N′, P′...sont respectivement les *homologues* des points M, N, P...Les droites telles que M′N′ et MN, qui joignent deux points d'un système et leurs homologues dans l'autre, sont des *droites homologues*. Enfin deux plans passant l'un par trois points d'un système et l'autre par les trois points homologues du système semblable, sont *deux plans homologues*. Cela posé, on démontre : 1°, que, dans deux systèmes semblables et semblablement placés, deux *droites homologues* quelconques sont parallèles, et que leurs longueurs sont entre elles dans le rapport des distances de deux points homologues quelconques au pôle commun; 2°, que les plans homologues sont parallèles; 3°, que les angles plans, dièdres ou polyèdres homologues sont égaux.—Deux systèmes peuvent être semblables sans être semblablement placés; mais il faut pour cela qu'il soit possible d'en construire un troisième égal à l'un d'eux et en même temps semblable à l'autre et semblablement placé par rapport à un pôle commun. On démontre aisément d'après ces principes que deux systèmes semblables à un troisième sont semblables entre eux.

* L'importance du dessin pour toutes les spécialités (mécaniciens, constructeurs, métallurgistes ou chimistes) a décidé le Conseil des études à ajouter cette condition d'admission au programme de 1840. Ainsi préparés, les élèves se livreront avec beaucoup plus de fruit aux nombreux travaux graphiques que l'enseignement de l'Ecole exige.

† Les élèves peuvent prendre pour guide, en cette partie de leurs études, l'ouvrage intitulé *Résumé des Leçons de Géométrie analytique et de Calcul infinitésimal*, par M. Belanger, professeur à l'Ecole Centrale.

Appendix F.

Technical Institute of Copenhagen.*

In Appendix D. reference has been made to a Bavarian school for the instruction of carpenters, masons, and others engaged in building; and the Technical Institute of Copenhagen is here described as a similar institution for artizans generally. The chief object of the institution, which owes much of its success to the unwearied labours of the veteran Academician Hetsch, is to teach drawing in its application to special branches of industry. It is, in fact, a systematized mechanics institute, and a people's school of design, not devoted to designers only, but to artisans of every class. The income of the school is very moderate, being at present only 366*l.*, all of which, with the exception of 500 rixbank dollars, is furnished by subscriptions and fees. This income is, however, insufficient, and its smallness prevents the natural development of the school. Cramped, however, as the school is by its limited means, there were on my visit no less than 15 teachers and 520 scholars. The fees paid by the latter are small, varying from 1 to 3 dollars per quarter. There are two classes of students, "the confirmed" and "the unconfirmed." Much importance is attached in Denmark to the rite of Confirmation, the attestation of which is considered an essential moral testimonial for employment; hence the above division of scholars is a common one in industrial schools, but really signifies little more than that the ages are below or above 16. Out of the 520 pupils attending during my visit to the school, only 80 were unconfirmed or were youths under 16; the remainder being artisans in full employment, or who were being educated for a trade. The latter attend the school all day, the former spend their leisure hours there, chiefly in evening classes. The subjects taught are as follows.

Subjects taught at the Technical Institute.

Hours in a week.	Classes.	Subjects.
Each class meets twice in the week for two hours each time.	A.	Elementary drawing.
	B.	Drawing, for carpenters.
	C.	Drawing, for masons.
	D.	Modelling in clay and wood; wood-cutting.
	E.	Drawing, for cabinet-makers, upholsterers, and turners.
	F.	Drawing, for tinplate workers, lockmakers, and gunsmiths.
	G.	Lithography and engraving.
	H.	Drawing, for harness-makers, wheelwrights, and carriage builders.
	I.	Drawing, for machine-makers, watchmakers, and opticians.
	K.	Chiselling and embossing.
	L.	Drawing, for goldsmiths, coppersmiths, lamp and gasfitters, Hardware workers, and glaziers.
	M.	Ornamental drawing, for porcelain painters, carpet manufacturers, bookbinders, and fringemakers.
4	N.	Geometrical, free, and ornamental drawing for the "unconfirmed."
16	O. & P.	Elementary drawing.
14	Q.	Decorative painting.
7	R.	Drawing for builders.
5	S. T.	Drawing for journeymen and apprentices.
2	U.	Mathematics.
1	V.	Building materials.
1	X.	Practical arithmetic.
1	Y.	Book-keeping, contract reckoning, &c
1	Z.	Physics.

* I regret that the necessity of keeping the Lecture within the usual limits prevents me entering into the extensive information on general education in Denmark furnished to me by my many kind friends in Copenhagen, among whom I would express my obligations to Professor Forchammer, Academician Hetsch, Magister Hammerich, Professors Steenstrup, Scharling, Jorgensen, and Hammel. I would also recall with pleasure the polite attention and facilities offered to me by Mr. Simoni, the Minister of Worship and Education and Commander Steen Bille, the Minister of Marine.

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GOVERNMENT SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

MUSEUM OF PRACTICAL GEOLOGY.

2nd Session. 1852-53.

The importance of the mineral wealth of the United Kingdom far exceeds that of any other European State, and furnishes four ninths of the raw mineral produce derived from all Europe. Although the annual value of the mineral produce of this Kingdom amounts to 24,000,000*l.*, and the capital and labour employed in its extraction and application represent a much larger sum, no school having for its especial object the instruction of persons engaged in mining operations had, until last year, been established in the United Kingdom.

Mining Schools have long existed in France, Russia, Prussia, Saxony, Austria, Spain, Sweden, and other countries even less connected with mining; and their practical value is recognized by the fact, that the respective Governments of these States have found it necessary to develope still further the educational resources of such institutions. The want of similar establishments in this country has long been felt in mining districts, and has been expressed both in Parliament and in memorials addressed to the Government. In the Report of the Committee

of the House of Lords (1849), the Committee observe that "among those best qualified to speak upon this point, a want appears to be felt of facilities for acquiring mining education, such as are provided by the mining schools and colleges established in the principal mining districts of the Continent, apparently with the most beneficial effects." Memorials have been presented from the principal mining districts of the Kingdom, urging this want, and indicating the Museum of Practical Geology as the proper institution to be converted into a Mining School. In consequence of these representations, and of the enlargement of the Museum, the Government have applied the resources of the institution to public instruction in Mining, and in the applications of Science to the Arts.

Although the intention always was entertained, as shown by the name of the school, to include instruction in the applications of Science to the Arts, various circumstances have occurred which have induced the Professors to give prominence to this kind of instruction, as well as to the mining education so much required by this country. A strong feeling on the part of the public has been manifested for the establishment of schools professing instruction in the Arts. This feeling has found expression in memorials to the Commissioners of the Exhibition from Birmingham, Bristol, Hull, Nottingham, Sheffield, and other towns; and the Educational Council of this school have thought it expedient to enlarge the character of the instruction, so as to include the more important applications of the Sciences professed by the Lecturers to the Arts and useful purposes of life. The Museum has in consequence been enriched with illustrative collections of the progressive stages of mineral manufactures, its foundation at present not enabling it to include the organic manufactures, which are, however, illustrated by the lecture collections of the individual Professors.

The Laboratories and working rooms of the several departments are so arranged and organized, that systematic studies in Chemistry, Metallurgy, Geology, Palæontology, Physics, Mineralogy, and Mining, may be entered upon with great

advantage under the direction of the officers of the respective departments. The Museum itself is of an essentially practical character, and was primarily intended to bring Science to bear on Geology in its application to the useful purposes of life; its officers were selected with a view to carry out the educational character of the institution, recognized shortly after its formation by an official letter of the Chief Commissioner of Her Majesty's Woods, and sanctioned by the Lords of the Treasury.

The following is a list of the officers entrusted with the courses of instruction:

PRESIDENT.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.

CHEMISTRY, applied to the Arts and Agriculture -	*Lyon Playfair*, Ph. D., F.R.S.
NATURAL HISTORY, applied to Geology and the Arts - - - - - - - - -	*Edward Forbes*, F.R.S.
MECHANICAL SCIENCE, with its application to Mining - - - - - - - - -	*Robert Hunt*, Keeper of Mining Records.
METALLURGY, with its special applications - -	*John Percy*, M.D., F.R.S.
GEOLOGY, and its practical applications - - -	*A. C. Ramsay*, F.R.S.
MINING and MINERALOGY - - -	*Warington W. Smyth*, M.A., F.G.S.

The education contemplated in this School differs essentially from that given in colleges, where general education is the primary object. Although it is intended to give general instruction in Science, to those who may require elementary knowledge, still, the chief object of the Institution (to which everything else is made subsidiary) is to give a practical direction to the course of study, so as to enable the student to enter with advantage upon the actual practice of Mining, or of the Arts which he may be called upon to conduct. The students forming the different classes are subjected to regular and frequent examinations, both written and oral, in addition to those which are required for the Duke of Cornwall's Exhibition. As an example of these examinations a few of the papers are appended. It may therefore be desirable to call attention to the peculiar features of the Institution, and to the Courses of Lectures to be given by the respective Professors.

The Museum.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum, has afforded great facilities for making complete collections illustrative of the applications of Geology to the useful purposes of life. These collections contain an extensive series of rocks stratigraphically arranged, with reference to their mode of accumulation, and the subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used for constructing public works and buildings, and of those employed for ornamental purposes, or for the useful arts in connexion with chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are carefully exhibited, and illustrations of the finished products are also displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiar excellences of manufacture.

Models of mines, mining tools, and working models of mining machinery, are collected, with the view of exhibiting the various modes of working carried on in different districts. The Museum is open to the Public for the first three days of the week, the remaining days being reserved for study.

Geological Surveys.

The Geological Surveys of the United Kingdom are carried on under the general direction of Sir H. T. De la Beche, and their central office is at the Museum. In this office the maps and sections are prepared and deposited. The field surveys are carried on in the localities under examination for the time being, and it is contemplated to communicate instruction in the field in the various departments of Geological Surveying, under the Mining, the Geological, and the Palæontological Professors.

Office of Mining Records.

This office, superintended by Mr. Robert Hunt, is established for the preservation of Mining Records. The absence of these needful documents was found to be the cause of much waste, in attempts to work in localities where there was little prospect of success, or where from a want of proper knowledge of the old workings much useless expenditure was incurred. A large collection of plans and sections of mines, and many important statistical mining details, are deposited in this Office, and are made available for the instruction of students.

Laboratories.

Two Laboratories, one for General, Practical, and Analytical Chemistry, under Dr. Lyon Playfair, the other for Metallurgy and Assaying, under Dr. Percy, are established in the Museum. Students will, under certain regulations, be admitted into the Laboratories for the purpose of receiving instruction in the analysis of minerals and ores, and of the methods used in applying them to useful purposes in the Arts.

Unless the student has already become acquainted with Practical Chemistry, it will be requisite to pass through the Chemical Laboratory before entering that for Metallurgy, as the latter requires previous chemical knowledge before its study can be usefully entered upon.

Palæontological Department.

As the relative age and sequence of geological formations are, to a great extent, determined by the fossils they contain, it has been found necessary, in the prosecution of the Geological Survey, to attach a department of Natural History, under the direction of Professor E. Forbes, where the organic remains contained in the sedimentary rocks of the British islands may be examined and preserved. Extensive collections of these fossils are arranged, and used for the instruction of students.

The following Courses of Lectures will be given during the Session :—

Chemistry.

The instruction in Chemistry is given both by Lectures and in the Laboratory. The lectures explain the general laws of chemical affinity and combination, the physical forces connected with chemical phenomena, and their application to useful purposes. The elementary bodies and their compounds are discussed, and especial importance is given to the practical appliances of the different substances described. The processes used in the chemical arts, and the manufactures chiefly depending on the application of chemical principles, are treated of in detail. The chemical facts of importance in their applications to mining and engineering, in the treatment of soils, and the conversion of mining products into substances useful in the Arts, are fully discussed. Organic Chemistry is so far entered upon, as is sufficient to enable the student to study more fully this important branch of the science; and its applications to the Arts and to Agriculture receive especial attention. In the Laboratory the students are taught the processes of qualitative and quantitative analyses.

Natural History applied to Geology.

The subjects of this Course include the principles of Natural History, considered especially in their bearing on geological evidence; the organization of extinct creatures compared with and illustrated by that of existing animals and plants; the history of the successive aspects of animal and vegetable life during the different geological epochs; the examination and description of organic remains, and the application of them to the determination of strata. The practical bearings of Natural History on the Arts will be illustrated in a separate Course.

Mechanical Science.

This Course will embrace a full consideration of the mechanical powers and the laws of motion, with illustrations taken from such sources as appear to furnish the largest amount of practical information. The laws by which the motive powers applied to machinery are regulated, will receive close attention and ample illustration.

The phenomena of Heat and Light, and the application of our knowledge of these physical forces to purposes of utility, together with Electricity in all its modifications of condition, and particularly Magnetism under the new and important aspects which recent discoveries have given it, will form the subject of examination. The explanations of natural phenomena afforded by Physical Science are necessarily included in this Course.

Geology.

This Course includes the proofs of the origin of stratified and igneous rocks, with an account of the more important substances entering into their composition, and an explanation of geological terms. The terrestrial actions now in progress are also described, including the degradation and denudation of land, earthquakes, volcanoes, areas of elevation and depression, &c. &c. Also, a descriptive account of the whole series of geological formations, showing their stratigraphical order and manner of formation, the laws by which these are determinable, and their general economic applications. Especial attention is given to geological surveying and its economical bearings.

Metallurgy.

The course of instruction in Metallurgy consists of Lectures and practical demonstrations in the Laboratory. The Lectures embrace the following subjects:—a description of the metals

and such of their compounds as are of metallurgic importance; ores; modes of extracting the metals from their ores; furnaces, crucibles, &c., and the materials used in their construction; fuel; fluxes; slags; methods of assaying; alloys. The smelting of iron, copper, and lead, and the manufacture of steel, are discussed at considerable length; as also is the treatment of silver ores by the "wet" and "dry" ways, and the refining and "parting" of the precious metals. The important branch of Electro-metallurgy is treated of in detail. The principles involved in metallurgic processes are expounded with special reference to practical application.

Mineralogy.

The Course embraces Crystallography and the physical properties of Minerals, treated principally with a view to the practical discrimination of the substances considered by this science; the elements of the Chemistry of Mineralogy, with the use of the blowpipe, and such simple tests as fall within the province of the field mineralogist, and the Physiography, or systematic description of Minerals, with particular reference to their mode of occurrence, and the uses to which they are applied.

Mining

Involves general considerations on the principles and management of subterraneous workings, the Practice of Mining in this and other countries being taught under the following heads:—Boring, and preliminary researches; Tools, employed in mining; shafts and sinking; levels and driving; the methods of securing excavations by masonry, timbering, and tubbing; "exploitation," or the working away of veins and strata; transport and winding, with the machinery and apparatus required; pumps and pumping engines; ventilation; and the mechanical preparation or dressing of ores.

H.R.H. The Duke of Cornwall's Exhibition.

H.R.H. the Prince of Wales, as Duke of Cornwall, has granted annually two Exhibitions of thirty pounds each. One becomes vacant every year, and will be competed for by Matriculated Students only, at the end of the first Session. It is held by the successful competitor for two years.

Working Men's Lectures.

Lectures intended for Working Men, and explanatory of the collections of the Museum, are delivered occasionally during the year, and to these Lectures the Students are admitted.

Regulations as to Admission.

Persons desirous of entering as Matriculated Students, with a view of eventually obtaining the diploma of the Institution, must be at least 16 years of age, and will be required to bring certificates or other evidence of their having received a sufficient preliminary education. They shall pay *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the Courses of Lectures extending over two years, and field instructions, according to the regulations of the Institution; and shall have the privilege of studying in the Museum and in the Library.

The charge for instruction in the Laboratories (which is not included in the above) is *thirty pounds* for the Session of ten months, or *fifteen pounds* for the Term of five months. The Laboratories are open to Occasional as well as Matriculated Students.

Occasional Students will be admitted to the Lectures on payment of *four pounds* for each Course of above 30 Lectures, and *three pounds* for the Course of 30 and under.

Acting Mine-Agents and Managers of Mines are admitted to the Lectures at half the above charges.

Officers of the Army and Navy, in the Queen's or the Honorable East India Company's Service, are admitted on similar terms.

Field instruction in Geology, Mineralogy, and Palæontology will be given to a limited number of OCCASIONAL STUDENTS, at a charge of *five pounds* per month.

The Session will commence on Wednesday the 3d of November, at Three o'clock, with an Introductory Address by Dr. Playfair.

Particulars respecting the times of Lectures, and all other information, may be obtained by application to Mr. TRENHAM REEKS, Curator of the Museum of Practical Geology, Jermyn-street, London.

APPENDIX.

The following papers are given as an example of the written examinations.

SESSION 1851–52.

CHEMICAL EXAMINATION.

12th May 1852.

1. What is the absolute evaporating power of a Coal of the following composition?—

Carbon	84·72
Hydrogen	6·43
Nitrogen	1·21
Sulphur	0·84
Oxygen	4·80
Ashes	2·00
	100·00

2. If 100 grains of the above Coal be burned in air, what bulk of air is required for the combustion? What products result from it? What is the weight of each product, and what the bulk of Carbonic Acid produced?

3. Explain the Dutch and French methods for making White Lead, the theory of the processes, and the formulæ of the products.

4. In what respect do air limes and hydraulic limes differ? Explain the manner in which each respectively acts.

5. The following substances being mixed together in powder, how would you distinguish both Acids and Bases?—

Arseniate of Baryta,
Selenide of Silver,
Chromate of Lead,
Silicate of Lithia,
Stannate of Soda,
Tartrate of Antimony.

6. Describe the relation between specific heat and atomic weight.

7. The following observations are made in analysing a gas :—

Observations.	Volume.	Temp.	Barometer.	Col. of Mercury above that in trough.	Corrected vol. at 0° C and 1 Metre Pressure.
Gas used (moist) - -	114·0	16·0	761·4	72·1	72·8
After absorption of Carbonic acid (dry)	111·4	15·8	760·6	74·7	72·2
After absorption of O (dry) - -	97·5	15·5	749·9	89·8	60·0
Gas used (moist)- -	78·6	15·4	750·6	226·1	38·1
Oxygen admitted (moist)	156·3	15·3	751·0	148·1	87·3
After Combustion (moist)	130·0	15·5	751·0	174·7	69·3
C O^2 being absorbed (dry) - -	113·9	15·3	751·2	191·0	60·4
Hydrogen admitted (dry)	273·2	14·6	752·3	32·2	—
After Combustion (moist)	163·8	14·4	752·3	140·7	—

Correct the two last observed volumes for temperature, pressure, and tension of aqueous vapour, giving the corrected volumes at 0°C and 1 metre pressure. Calculate from the numbers in the last column, the composition of the mixed gases in 100 parts.

8. A salt containing potash, lime, sulphuric acid, and water, being analysed gave the following results :—

10·05 grs. of the salt gave 3·05 grs. carbonate of lime, and 14·85 grs. chloride of platinum and potassium.

9·28 grs. of the salt gave 0·51 grs. water, and 13·22 grs. sulphate of barytes.

What is the composition of the salt in 100 parts, and what is its probable formula?

LYON PLAYFAIR.

EXAMINATION IN NATURAL HISTORY APPLIED TO GEOLOGY.

13th May 1852.

1. Explain the terms *Species* and *Genus*.

2. What do we mean by *Provinces in Time* and *Provinces in Space*?

3. Enumerate the *principal groups* of organized beings according to their relative value with respect to Geological evidence.

4. What *portions of the bodies* of Vertebrata, Articulata, Mollusca, and Echinodermata are likely to be preserved in the fossil state?

5. Enumerate and define the *orders* of Corals, according to the classification of Milne Edwards, and Haime; state their geological distribution, and the amount and nature of the evidence they severally afford respecting the climates of past epochs.

6. State the distinguishing characters of the *orders* of Mollusca.

7. Enumerate and define the *extinct genera* of Echinidæ; and state the geological distribution of each.

8. Enumerate and define the *tribes* and *genera* of Brachiopoda, of which species occur in a fossil state; and give the geological range of each.

9. Enumerate and define the *genera* of Tetrabranchiate Cephalopoda. State the characters and geological range of the sub-divisions (according to Von Buch) of the genus Ammonites.

10. Explain the structure of a Trilobite, and enumerate and define the leading *tribes* of Trilobites.

11. What are the *genera* of Invertebrate animals that usually occur in a stratum of fresh water origin?

12. What *genera* of Radiata and Mollusca are exclusively Palæozoic?

13. What *genera* of Radiata and Mollusca are exclusively Mesozoic?

14. Describe minutely the specimen placed before you.

EDWARD FORBES.

EXAMINATION IN MECHANICAL SCIENCE.

14th May 1852.

1. Give an example of simple and of compound Motion, and explain the parallelogram of Forces.

2. Define the laws of Gravitation, and examples of each law.

3. A Stone is liberated at the height of 26,000 feet above the level of the sea; neglecting the resistance of the air, in how many seconds will it fall to the ground, and what will be its final velocity?

4. A body is projected vertically from the earth with an initial velocity of 240. Define its velocity during each second of ascent. At the end of how many seconds will it begin to fall?

5. Describe the different phenomena produced by superficial attraction, or the adhesion of, and to surfaces.

6. Give the laws regulating the motion of a pendulum under different conditions of length.

7. Define the laws of the pressure of slightly elastic fluids, and describe their application in the Hydraulic Press.

8. Upon what does the action of the Hydraulic Ram depend?

9. In a vessel kept constantly full of water, there are orifices at the depths respectively of 3, 5, and 9 feet. Give the ratio of the velocity of efflux from each.

10. Give the laws of atmospheric density and elasticity, and the relation of volume to the compressing force.

11. Upon what principle depends the application of the Barometer in measuring the heights of mountains?

12. Describe the operation of Steam in an Engine working "expansively"; and the differences between a single acting and a double acting Steam Engine.

13. Give some examples illustrating the conditions of sensible and latent heat.

14. Define the spaces occupied in the prismatic spectrum by the luminous, calorific, and chemical forces.

15. Define the terms Chromatic Aberration and the aberration of Sphericity, and the principle of the construction of achromatic lenses.

16. What are the conditions of a charged Leyden Jar, and point out some analogous conditions in natural phenomena?

17. Define the expressions, *quantity*, and *intensity* as applied to Voltaic Electricity; and describe the Voltaic arrangements necessary to produce these conditions.

18. Give the law of electro-chemical decomposition.

19. What is the relation between the mechanical power of an electro-magnet and the chemical action in a voltaic battery?

ROBERT HUNT

EXAMINATION IN MINERALOGY.

15*th May* 1852.

1. What portions of the Inorganic Kingdom are considered by modern authors as belonging to the province of Mineralogy?

2. Give the derivation and meaning of the word *crystal*, and the reason for crystals being looked upon as the *individuals* of the inorganic world.

3. Define a *rhomb*, a *pyramid*, a *tetrahedron*, and an *octohedron*.

4. Describe the method of projection applied to the drawing of crystals, and draw a cube on this principle.

5. How are the axes placed in the *oblique system* of crystallisation? and by what names do you distinguish the two axes which are not vertical, and the horizontal prisms which are produced by modification in those directions?

6. Enumerate some of the irregularities of the surfaces of the faces of crystals.

7. Describe the principle of the *contact* and of the *reflecting Goniometer*.

8. What is meant by *simple* and by *double refraction*, and state what relation appears to exist between these phenomena and crystalline form?

9. Mention some instances of *Isomorphism* in mineral substances, and of the difficulties arising hence, in carrying out a strict scientific arrangement.

10. What are the leading principles of the arrangement adopted by Werner, by Mohs, and by Berzelius?

11. Describe the chief characteristics and localities of the *Diamond*, of *Graphite*, and *Anthracite*.

12. What is the crystalline system, and what the ordinary form of *Quartz?* and enumerate the varieties generally known under other names.

13. Describe the external and chemical characters of *Hornblende* and of *Augite*, pointing out wherein they differ importantly, and with what classes of rock they are associated.

14. What is the generally occurring form and the chemical constitution of the gems termed *Emerald*, *Garnet*, *Amethyst*, *Topaz*, and *Zircon* or *Hyacinth?*

15. What are the chief characteristics of the ores of Manganese called *Pyrolusite*, *Manganite*, *Braunite*, *Hausmannite*, and *Psilomelane?*

16. Describe four of the most important species containing Lead. Draw a crystalline form from the Cubical System, showing a combination of faces of the Cube and Octohedron; and from the Rhombohedral System, showing the combination of faces of the pyramid, prism, and terminal plane; distinguish the faces by their proper symbols, and state which of the species described assume such forms.

17. What are the minerals most valued as ores of Copper? In what systems do they crystallize, and what are their chief constituents? By what methods is the presence of this metal in its ores readily detected?

18. Which of the precious metals occur in a native state, and under what circumstances?

19. Mention the Crystalline System and form of the models of crystals placed on the table.

20. Give the name and chief characteristics of the minerals lettered A, B, C, D, E, F, G, H, I, K.

WARINGTON W. SMYTH.

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Box 14

SCIENCE

IN ITS

RELATIONS TO LABOUR.

Being a Speech

Delivered at the Anniversary of the People's College, Sheffield, on the 25th October, 1853.

BY

LYON PLAYFAIR, C.B., F.R.S.

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NOTE. — *The Author had no intention of printing this Speech when it was delivered, or it would have been prepared less with reference to its immediate and local purpose; but at the request of the People's College, and of some of his Educational friends, he has consented to have it published.*

SCIENCE IN ITS RELATIONS TO LABOUR.

I HAVE overcome a strong natural repugnance to take the chair at public meetings by consenting to preside to-night, and I have done so, because I view this institution, justly called the "People's College," as typical of the strong desire of the industrial classes to keep up with the rapidly-changing phases of the age in which we live; and because it is founded on the only principle which can insure the permanent success of such institutions—self-support and self-government. You have now had five years of existence as a separate institution, and your Reports continue to give evidence of an increasing success. It is no small matter of congratulation for your Committee to be able to inform you, that during these five years, 2500 persons,—not only men, but also, I am glad to say, women too,—have benefited by the instruction given in your school. I have read with interest the four previous Reports of the College, and all of them give progressive evidence that it is not dead to its true mission, and that its supporters do not think they have yet fulfilled it by the

character of the instruction which is now given. The College had to battle, as all Educationalists have to do in their respective spheres, with the deficiencies of elementary instruction, and it very properly grappled with this difficulty at its outset, and devoted its chief attention to the rectification of the deficiencies of primary education among its members. But it soon began to expand itself, throwing out now and then new and higher courses of instruction to its students, as they became fitted to appreciate and receive them; and accordingly we find Logic, Natural Philosophy, and Chemistry appearing on its class lists. All this only being indicative of the mission of the People's College, before proceeding further, let us examine the public wants which are gradually arising, and which must be satisfied if this School and other similar institutions are to prosper in the future.

There are probably few, if any, persons within these walls who are not supported by *labour* in its true signification. Labour, properly comprehended, includes work performed, either mechanically by the hands or intellectually by the brain; and one may involve as hard work, and as fatiguing or wearying to the body, as the other. In fact, it is difficult to divide labour by definitions, for there is scarcely any mechanical labour that does not require thought, just as pure thought requires mechanical labour in its expression.

Now it becomes the working man, be his labour chiefly mechanical or chiefly intellectual, to consider whether its value is likely to remain permanent. If we are living in a sleepy, slow-moving age, this question little concerns our individual interests, and we may jog on lazily with the times without our material welfare being much affected by the abstract truth.

But as it happens that we are living in a period when locomotives run screaming past horse-drawn barges on canals; when lightning carries our messages by telegraph to London, in less time than the old post-haste messenger of a former period could have saddled his horse; and when steam not only prints but scatters the world's news of the morning over the whole breadth of the land before the sun has well set, it is surely wise in us to consider whether we are advancing with the progress of events: for if we do not, depend upon it that we shall, like Rip Van Winkle, awake some morning and find that we are a generation behind, all things having altered since we fell asleep.

It is, in fact, easy to recognise the causes which are making this age a transitional one. When steam projects everywhere, not only the raw material but the finished manufactures, production ceases to depend upon brute force or local advantages, but for successful competition relies upon intellect. Mr. Smyth has shown how the mineral riches of a district act upon the character of its population. In early ages the soft and massive sandstone of Egypt gave rise to its stupendous architecture, whilst its monolith statues and obelisks arose from its syenite, so easily worked and polished. The marble of Pantelicus and the silver of Laurion influenced the grandeur of the Parthenon, and perhaps gave remote birth to the sculptures of Phidias and general life to Attican art. The abrupt ravines of Lycia and of Arabia Petræa created their peculiar architecture, just as the clay of China and Japan gave rise to their pottery, and the cotton of Calicut to calico. In the early history of manufacture, the mere accident of mineral or organic wealth fixes the business of a district, and impresses a character upon its people;

just ... at present the mineral riches of Servia and Bulgaria account for the activity of their inhabitants, and for the contrast between their energy and the torpor of the Sclavic hordes in the plains of Russia. All mere local advantages are of small importance in this age. Our vessels do not creep along coasts, as in former times, but boldly march over unpathed oceans, with a power so certain and independent of weather, that few ships would accord space to the great present, given by Æolus to Ulysses, of all the hostile winds packed up in bags.

Labour is now the great element in competition, and the raw material is of less value in the cost of production. This is surely the case, or Sheffield could not compete with Sweden in cutlery; nor could a Manchester mill send calico to America, whence it derived the cotton. But this labour, which is so important in production, is either mere animal power, or it is a skilled application of force. The history of the times shows us, that while skilled labour is constantly increasing in value, mere brute force, like raw material, is constantly decreasing as an element in the cost of manufacture. The labour of the man in spinning and weaving is now substituted by that of the girl and the boy, the power of the steam-engine having rendered the full strength of the man unnecessary. The brute strength of the man is less in demand, but his intellectual force is continually rising in value. All this change has resulted from the more general use of natural forces. Penelope required twelve slaves to grind corn for her small household, while now the same number of freemen in a mill grind a daily supply of corn for 60,000 men. A blast of gunpowder fired by one man, detaches in an instant a mass of

rock which that one man, by manual labour only, would have required a lifetime to effect.

Thus natural forces are constantly substituting brute force, and man is called upon to use God's laws when he discovers them, and to spare the sweat of his brow by the conception of his brain.

The man that sees not this substitution to be the inevitable result of a God-born law, has studied to little purpose. If he still rely on mere animal labour, apart from its intellectual training, as sufficient to do battle with advancing competition, he will meet with that amount of success which the imperial general, Siu, experienced a short time since, when he drove many thousand buffaloes, with flaming torches attached to their horns, to scatter desolation in the ranks of the Chinese rebels; who, better understanding the use of this misapplied animal power, fed upon them, and thus acquired strength to rout their opponents. Just as at the siege of Arcot, the metal-coated elephants, sent as living battering-rams to batter down the gates, were turned away by the better-applied force of an eighth of an ounce of gunpowder, projecting an ounce of lead from an iron tube. In fact, no law of nature can be broken without injury, not only to the breaker of the law, but also to the instrument employed. Think of the recent revelations of the crank system in our prisons. It is a positive physiological law, that muscular substance is expended in every manifestation of force, and that the organs thus deteriorated can only be repaired by certain ingredients in food. But in the crank system of certain of our prisons, a man was forced to do a great quantity of work, and if his strength failed, he was deprived of food as a punishment, and placed again to complete it. This is only

one out of many cases of the intense ignorance of science among our educated classes. It is, in fact, equivalent to the act of an engineer who, wishing to get more work out of his engine, raked out the fuel from under the boiler which gave to it the steam, and when the engine stopped from want of its motive power, dashed it to pieces because it did not fulfil his wishes.

To understand still further the effect of science on labour, you must not suppose that because natural forces are being employed in place of animal unskilled labour, that, therefore, human labour can ever be dispensed with. In all applications of natural forces, labour is requisite to put them into operation. The labour of man applied to fuel and water produces steam, and this drives an engine which performs certain duties. It is useless to ask whether the man does most, or the heat most, in the work; it would be like discussing which side of a pair of scissors was most useful in cutting, or whether the upper or lower jaw is of most use in chewing. Notwithstanding all the applications of machinery, and of other natural forces to production, it cannot be said that animal labour has less influence than formerly, although it is quite certain that a smaller amount of mere muscular force is required, while a larger amount of skilled or intellectual labour is necessary. This theoretical conclusion has lately received a practical sanction of the highest character. Mr. Whitworth, the eminent machinist of Manchester, lately visited the United States as a Government Commissioner; and I am informed that he has returned home with the conviction that the superior intelligence of American workmen enables them to use machinery of a high order, to compete with which

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a scientific education of our artisans is absolutely necessary.

It cannot be too strongly impressed upon your convictions, that we creatures never create new properties in any substance; all that we are permitted to do is to use properties already inherent in bodies, and combine them into utilities.

Iron ore is taken from the ground; its oxygen is removed by fuel, and the product is iron: which is no creation, but only the resolution of a body into its simple state. This iron, as it comes from the furnace, you use for castings; or you burn off some of the carbon combined with it, and it becomes malleable; or, united more intimately with carbon, it is steel. In all this man has done little; he has been allowed to adjust the play of chemical forces, and three utilities have resulted, but not one property has been created. You convert the iron into a poker and stir the fire; or, in other words, oxygen is enabled to carry on its affinities with the carbon; then the fire burns and boils water, the steam of which turns round grindstones and enables you to produce tools. But in this sequence of operations you are only the slaves of natural forces, and they are not slaves to you. They perform in one regulated line functions assigned to them from eternity, and all your artifice will not make them turn one hairbreadth from the course assigned to them by the great Creator. Labour is, therefore, not creative of forces, nor of properties in bodies, but is only the arranger of them, so as to produce utilities.

If you are convinced of this, it does not require much argument to prove that it would be much better to make yourselves the friends rather than the slaves of natural powers. As long as labour is carried on in a

blind ignorance of causes, the labourer is the slave, not only of the natural law under which he acts, but also of the superior intellect which applies the law to his purpose. But immediately that the labourer has an intelligent understanding of the law of nature under which his work proceeds, he is no longer the blind slave of the law, but its valued ally; while he becomes the friend of the presiding intellect, and co-operates more effectively with him in the production of the desired result.

I do not mean to say that both master and man may not carry on a trade without a knowledge of the laws of nature under which they work: unhappily, this is too common to be doubted. But I do coincide with Mr. Moseley, that, in thus going on in ignorance of the principles of their avocations, they are losing one of the highest enjoyments of intellectual beings, the application of the reasoning powers and of the understanding; and that they do not possess the position within their reach of moral dignity and self-respect.

Do I deceive myself when I think that this is the feeling in your own minds in the establishment of the College, although circumstances have not yet enabled you to realise the whole intention?

I would rest the argument chiefly with you in this light, that a knowledge of Science is necessary for you in your trades, in order to exalt your understanding and enable you to fulfil your functions as intellectual beings. I would not ask you to view Science only as regards its immediate utility to your avocations, although abundant evidence of this might be given to you.

There are many who look at Science only in this bread-and-cheese point of view—who cannot sympathise with philosophers when they traverse through space

and commune with the stars, or look for the cause of the glorious blue of the vaulted sky or of the many colours of the rainbow which arches the heaven; but they will fall down and worship Science when it tells them how to prevent butter from becoming rancid, or how to boil beef in an economical fashion.

Science is to prostrate itself and worship the golden calf, and not the real Creator.

But Science is a religion, and its philosophers are "the priests of nature."

When we lead our children to the study of the revealed word of God, it is not with the view of making them good housewives or good nurses to us in our old age. It is for the higher purpose of glorifying the Creator of all things, although it does happen that these worldly benefits are accorded to us by the same act. Just so with Science: study it yourself, and encourage philosophers to study it for its own sake, without a gold-seeking love, and you will find that she will shower down material benefits on your daily life.

The whole history of Science gives you this experience, that the great applications in industry and the advance in civilisation are mere offshoots in the growth of abstract truth. I have drawn attention to this elsewhere, but will yet venture to repeat some special instances.

That wonderful civiliser of our age, the Electric Telegraph, the winged messenger of thought, arose from a philosopher searching into the cause of convulsions in a frog's leg, which a Bolognese lady was preparing as a cure for her cold, some eighty years since. The art of Electroplating had birth in the construction of a battery for a philosopher's experiment; and Science gives you electric powers for this purpose contained in

small vessels, which you may appreciate the more when I tell you that the greatest thunderstorm which ever scattered its terrors over the world, does not contain enough electricity to gild a single pin. Franklin's discovery, by which he drags the fierce lightning innocuously into the ground, came from a consideration of the conducting powers of metals. A young man catches a ray of light travelling from a window in the Palace of the Luxembourg: before long the examination of this ray teaches mankind to avoid shoals at sea, to spear salmon, and to tell how much real sugar exists in specimens offered for sale. The chemical properties of the sunbeam are noticed, and the photographer, holding "his mirror to nature," carries away the reflexion captured by the sun. The philosopher observes that the play of light on mother-of-pearl is due to the interference produced by its grooved structure; and this knowledge is instantly applied to the manufacture of Birmingham buttons, made on the same principle. He tells you that the gorgeous colours of beetle-wings, and of the feathers of birds, result from the relative thickness of films, of which they are composed; and ere long De La Rue sends round wedding stationery adorned in a similar fashion. You see the philosopher poising his barometer in the air, scanning the clouds, and noting the temperature of the air and sea, and before a few years navigation is changed by the observations. The storm and its course are explained, and the enlightened navigator, with good sea-room, no longer dreads it, but uses it for his own purpose. The route to America is altered by the fact of Franklin dipping his thermometer into the Atlantic, and ships now go from London to New York and back again in less time than they used to go to Charleston,

the old half-way house. The recent development given to the abstract study of Meteorology by the liberality of the American Government has led, within three years, to the most material benefits; for already has a new route to the Equator been discovered, and the voyage to California is much shortened (from 180 to 100 days); the regions inhabited by whales have been also described on charts, and the American Whale Fishery has risen to a state of unexampled prosperity.

I need not, I am sure, weary you with any further illustrations of the practical benefits which follow the overflowings of Science. It is your interest, as men devoted to industry, to watch its overflowings and to benefit by them; but recollect, that they are only contingent results of the disinterested study of abstract truth. It is also your interest, therefore, to see that the fountains of Science are always kept full. Unfortunately, this is frequently not the case in this country. Taking into account all the fellowships and other positions of our universities, and of analogous learned institutions, it is stated by Mr. Lorimer, that England only provides places for 1190 of the learned class to prosecute the study of the natural, physical, and the mental sciences, and of higher literature. The nation has not duly appreciated the necessity of providing for the support of a learned class so essential to its prosperity. Industry, occupied in the pursuit of the applications of natural laws, has cared little for the growth of Science in the abstract. You recollect that Nabis, the tyrant of Lacedæmon, had a mechanical figure disguised as his own lovely wife; and when a rich man approached, this pseudo-wife seized him in her mechanical embraces, until she had squeezed out all his riches. Manufacturing In-

dustry treats Philosophy in a similar way, hugging it in a close embrace until its riches are yielded to it, and then leaving it, to fatten again in poverty. The relations between Science and productive Industry will not be correct until the nation acts on David's military law, that those who stay with the stores shall share equally with those who go into action, or otherwise the stores will not be attended to. Nor is this a real difficulty in a national point of view, for the learned class, like Bacon in his youth, "have vast contemplative but moderate civil ends."

Depend upon it that I am right when, in recommending you to study Science, not only for the improvement of your understanding, but also to put yourself in a position with the transitional state of labour, I also urge you in a national point of view to look to the healthy growth of labour immediately applicable to productive industry, and also to that mental labour which gives to it its life and vigour. Though Adam Smith might have proved a bad merchant or an indifferent banker, the science of the Scotch professor laid down the principles of trade, by following which many of our politicians have profited and our merchants carved out their fortunes. Possibly Jeremy Bentham would have proved an indifferent administrator and a bad Lord Chancellor; but his views for the reform of the law and of the government have not been lost in modern changes. Theory and practice can never be more antagonistic than can a rule and a special application of it. If theory and practice were understood in their true relations, we would find the learned class and the manufacturing class appreciating each other much more than they do now. The dignity of productive industry would be recognised by the one

class, and that of productive talent by the other. In China, you are aware, the nobility and officers of Government are a learned class, and yet the dignity of labour is more appreciated there than in any other country; and an author, who writes commentaries on Confucius, boasts of his brother who paints screens and fans. In one of the latest proclamations of the Emperor of China, in which he announces that he has raised an Empress to the throne, to share with him the toils of government; after alluding to her various intellectual and moral virtues, he commends her as "not shrinking from washing fine or even coarse linen with her own hands."

Do not agree with the error of a great author, that Industry is the mother of Science, "the vigorous and comely mother of a daughter of far loftier and serener beauty." It has been well answered by Brewster, in a Quarterly Review, that Science never had a mother; that though she might not have come, like Minerva, full grown, and panoplied in complete armour, from the brain of Jupiter; though she might not have come a tree, rejoicing in its foliage, she came into the world a bud, containing within itself the principle of growth, and capable of elaborating its leaves for the healing of nations. Industry has often effected great progress without Science; but though Tubal Cain was skilled in brass, he was not the father of metallurgy; and though Noah knew the effects of the fermented juice of the grape, from him did not spring the laws of organic metamorphosis. The gopher ark did not raise the science of navigation, nor did the tower of Babel or the gorgeous temple of Solomon give birth to one scientific law. The greatest buildings of ancient times raised no theory of the mechanical powers.

I will presume, then, that you admit the desirableness of studying and promoting abstract science, in order that our country may keep pace with the change of events and with the efforts now making by foreign powers to raise such knowledge among their people. Let us, then, inquire how it should be accomplished in your case. I feel that the prudence and good sense which has guided your Institution in the past is its safest guide for the future; but if you will permit me to hazard any suggestion, it would be to say that the dangerous tendency of such schools is to attempt too much. An elementary school you must have, in order to correct the deficiencies of early education. This will each year become less necessary, from the improvement and extension of our schools. I think, therefore, it might be advisable for you soon to fix what is to be the character of your secondary education; and when you have done so, not to be tempted to extend it indefinitely, or to diverge into another course, from the accident of some zealous members being willing to instruct in special branches. Admit that it would be good policy to divide your College into a lower and higher division; the first for primary, the next for secondary instruction: by this division you would give a strong impulse to the pupils of the lower school to prepare for the upper. Then define what the secondary instruction is to consist of, and do not be tempted beyond a few subjects. If it is to be Science, I would confine it chiefly to Mathematics, Mechanics, Physics including Chemistry, and Mechanical Drawing.

The great success of the Edinburgh School of Arts, which teaches annually from 600 to 700 artisans in these sciences, is owing to this fact, that its Directors

first clearly defined the wants of the artisans of their district, and they have never been tempted out of the circumscribed sphere of usefulness. Your Reports give me the idea that you are just beginning to require a strict definition of your object, and that your ultimate success may depend upon such a limitation. If you are to be a school adapted to the artisans of your town, I am sure that you will be more useful by teaching a few subjects thoroughly well, than by attempting many perhaps indifferently. But I again say, with unaffected confidence in your management, that I believe the strong practical sense displayed in it will be sufficient to steer you clear of this danger, although I would have been unworthy of your reliance had I not pointed it out to you. I need not assure the Committee that I am always at their disposal, if I can be of any use to them in a consultation upon any points connected with your interests.

I have urged you gradually to supplement a secondary scientific upon your primary elementary instruction, but I must warn you, at the same time, that a higher scientific school will not succeed unless the primary education creates a taste for the science which you propose to teach with sufficient fulness to be of use to your ordinary avocations. The whole history of Mechanics' Institutions shows this. These were founded as secondary schools for adults, and with the express view of teaching the artisan the principles of his trade. But in this object they have failed, and the reason of this failure is instructive.

The managers of Mechanics' Institutions are of course obliged to suit the instruction to the taste of the members. Now no love for systematic scientific instruction existed, and the managers, trying to gra-

tify the ill-regulated demand for knowledge, fell into the most discordant teaching. Courses of lectures were alternated with Chemistry and Music; Astronomy and Table-turning; Natural History and Mesmerism; the Fine Arts and Ventriloquism; the Drama and Spirit-rapping. A false excitement took the place of real instruction, and the true objects of Mechanics' Institutions, if not forgotten, failed to be realised.

This false excitement, in the end, destroyed even the semblance of real instruction, and the well-wishers of the Mechanics' Institution soon lamented to find, not even the semblance of bread to all this intolerable quantity of sack. Much moral good is still done by them; and, after all, the thirst for mental excitement has quenched the thirst for gin: but our hopes may be allowed to rise to what they might do if they had rich land to culture, instead of a barren waste.

But the root of the evil is deeply fixed in the deficiencies of primary education. The primary instruction of our country (for education it cannot be called) is essentially faulty, in neither bearing on the future career of the pupil nor in drawing out his faculties. All the natural tendency of a child is in the direction of science; he is naturally a young Linnæus who tries to classify plants, animals, and stones, in his own little way. But, as Mr. Forbes remarks, blind to this natural instinct as a true indication of a real education, "plainly pointed out by nature, and developing itself according to the laws of its own God-given constitution, we prune and trim, bind and cramp, the youthful intellect into traditional and fantastic shapes, even as the gardeners of a past age tortured shrubs and trees into monstrous outlines, vainly fancying to

improve their aspect, arresting the growth of the spreading boughs and the budding of the clustering foliage, mistaking an unhealthy formality for beauty."

Words, to a great extent, have taken the place of *ideas* in education. It is not without its use to tell a child the Greek, the Latin, the French, and German for "sea;" but what conception of the ocean is thus conveyed to the child? Surely it might be interested by being told of its tides and currents; of its zones of distribution of vegetable and animal life, both as regards space and time; of the peaceful breezes which sweep its bosom, and of the fearful cyclone that lashes it into fury. Even in geography, verbalism chokes the growth of real knowledge. The child is taught a host of names of towns, and of the tributaries of rivers, from those of the Thames to those of the Obi or the Loa; but its attention is confined to the political boundaries of nations, often drawn in lines of blood around a country, and stereotyped in the evil passions of peoples. But how seldom are the faculties drawn out by showing the child with what beneficent purposes the Creator fashioned islands and continents, by the use of the sea, volcanoes and earthquakes, agents much more constructive than destructive! How rarely is the child taught to know the causes and balance of life involved in the apparently capricious but truly regulated recurrences of the everyday phenomena of wind, rain, dew, and snow! And, notwithstanding our neglect in teaching the people the ordinary laws of science upon which our existence depends, we are surprised when a current of pestilence sweeps along our unsewered streets, and, overwhelming our badly-fed people, swells itself by filthy tributaries, until it overflows its natural channels and spreads desolation in the ranks of the higher classes,

who neglected to communicate the intelligence of the age to the mass of the people.

But, even in our secondary education of the higher classes, these laws are little understood, and rarely form subjects for instruction. And yet, if one ventures to urge the necessity of an improved education in our great schools, he is looked upon as an educational democrat and a ruthless fellow, who would trample the graces of polite literature under the heel of mechanical vulgarity. We are told that we do great harm in asking those time-honoured schools to introduce new-fangled notions in Science, and thus possibly reduce the value of a long-acquired *experience* in education. The argument would be good, if we did not, with Jeremy Bentham, examine the true significance of the experience alleged as a bulwark against innovation. Experience in knowledge is the accumulated results of the wisdom of the past; but some of our great schools see no wisdom after the classical ages. Centuries of experience in human knowledge go for nothing as a means of drawing out the faculties; like the Tartars, the schools worship the *child* Buddha, but, unlike them, they refuse to worship him when grown to manhood. The learning and wisdom diffused by our great grammar-schools is worthy of the highest admiration, but why *confine* it to the learning and wisdom of the ancients? In one point, at least, the mental discipline of the grammar-schools is sadly deficient, and that is in inculcating habits of observation. The introduction of the Natural Sciences would go far to correct this deficiency.

You will see, then, that secondary institutions in Science, such as I wish yours ultimately to be, cannot greatly prosper until our general education is improved.

If the young tree be not tended in youth, it will not bear fruit in age; if you do not sow Science, neither can you reap it.

The Board of Trade Department of Science and Art has recently been established, with the view of promoting scientific and artistic instruction. State encouragement to the study of Art had been given, more or less efficiently, for fifteen or sixteen years; and the Department found much prepared, and a feeling for it already created in the public mind. With regard to Science it is different. The Scientific Division, added for the first time in April of this year, had many difficulties to surmount, and much to organise. The demand for it had in a great measure to be created, and not only apparatus and diagrams had to be made, but teachers to use them had to be instructed. You will scarcely be surprised, then, when I tell you, that as yet the Department is not in a condition to operate very actively in the direction of scientific instruction. Still, it has made considerable progress. The most eminent men, among whom it will only be necessary to mention Wheatstone, Willis, Snow Harris, Henfrey, Paterson, and Marshall, have liberally undertaken to superintend the preparation of diagrams and apparatus in certain branches of science, in which they are eminent, and and well-thought-out instructional series may be expected from their generous co-operation. These, when ready, will be manufactured cheaply, and be furnished to schools at half their prime cost. The instruction of teachers is scarcely commenced, but difficulties which have presented themselves to this will, probably, be soon surmounted. The Department is prepared to undertake the expense of the experiment of introducing scientific instruction into a town, by guaranteeing a

salary to the teacher during the period of trial; that is to say, by assuring to him a moderate means of support, if the fees of pupils do not reach the sum assigned for this purpose. All this implies that the system is not one of subsidy to a town, but a simple encouragement to local effort. The plan is framed on the belief that the instruction should be of a self-supporting character, and the management should, therefore, be clearly local and not central. Self-reliance, self-support, and self-government, are implied in this scheme of Government aid, which partakes more, therefore, of a friendly than of a paternal character.

In fact, the principle of the Department is exactly your principle,—that you should rely on yourselves and not be subsidised by the Government. But as it does not follow that artisans could bear the expense of an experiment, it offers, on condition of receiving your aid not to require its help, to be at the risk of the trial, which, with your very proper feeling of independence, would be no risk at all.

There are two classes of objectors to the diffusion of this higher class of instruction among the artisans of this country. The first class object, that if the artisans be educated in science, they will soar above their position and neglect manual labour. Admitting that this was the tendency of such education, an adjustment, on the principle of supply and demand, would soon be effected; for, unless they found a demand for their intellectual instead of their manual labour, the disposition could not be gratified. The same fear was expressed when the Royal Naval School at Greenwich began to educate sailors. Those who feared that an insubordinate spirit would arise with education kept it at a low

cbb, and a miserable amount of reading and writing, with the occasional variety of being attached to the whipping-post, was thought to be the orthodox education for the true British seaman. But, singularly enough, the Greenwich boy, in spite of this severity and ignorance, became a bad and insubordinate man, and captains of ships were thoroughly dissatisfied with the Greenwich contributions to their vessels. A bold change was then introduced, and the boys gathered up from the sweepings of Wapping and Portsmouth were treated with kindness, and viewed as fit subjects for intellectual training. They were now actually taught Mathematics, Chemistry, Mechanics, and Navigation, in addition to their elementary instruction. The latter did not suffer, but was much improved by the opening out of the faculties by the Sciences, and at the same time reading, writing, and geography were learned more efficiently. Nay, more, the boys were taught, as if they were to be captains, to take latitudes and longitudes, and to navigate ships, and at fifteen they were drafted, as of old, into the navy and into merchant-vessels. Did this high education unfit them for their position as ordinary seamen? On the contrary, they were found much more fit. There were far fewer desertions than formerly, with scarcely any records of bad behaviour, and the captains who declined their services before now eagerly demand them. It is true they rise in life, and from common seamen become warrant officers, or even mates and masters of ships. But this is just as it should be, and is a logical result of their increased knowledge. Depend upon it, that knowledge will never unfit a man to be a citizen of the world. Ignorance will lead a man astray, and, as the father of false notions, will give birth to an enemy to social progress; but true know-

ledge can only produce loyalty, patriotism, love of order, and love of duty.

The second class of objectors, who are now rare indeed, dislike the scientific instruction of our population, because they fear that it is apt to make men sceptical to the truths of religion. In regard to these objectors, I cannot understand their fears nor do I think it useful to argue the point with them. The opinion, in fact, resolves itself into an apprehension that a study of God's wisdom is likely to subvert God's truth. It is, in reality, to think that the contemplation of the infinite wisdom and power of the Creator is likely to alienate you from Him.

But if you are still told that the study of God's power as displayed in creation is likely to depreciate your love and veneration for the Creator of all things—refer the objector to that inspired word which gives you a warranty for the study :—

"But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee;

"Or speak to the earth, and it shall teach thee; and the fishes of the sea shall declare unto thee.

"Who knoweth not in all these that the hand of the Lord hath wrought this?

"In whose hand is the soul of every living thing, and the breath of all mankind."

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Introductory Addresses on the Science and Art Department and the South Kensington Museum.

No. 3.

ON

SCIENTIFIC INSTITUTIONS

IN CONNEXION WITH

THE DEPARTMENT OF SCIENCE AND ART.

BY DR. LYON PLAYFAIR, C.B., F.R.S.,

PRESIDENT OF THE CHEMICAL SOCIETY;

CHIEF INSPECTOR OF SCIENCE SCHOOLS, AND SCIENTIFIC REFEREE.

LONDON:

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AGENTS TO THE SCIENCE AND ART DEPARTMENT OF THE COMMITTEE OF COUNCIL ON EDUCATION.

1857.

Price One Penny.

AN ADDRESS,

&c. &c.

1. In the Introductory Lectures which are at present in progress by the various officers of this Department, we desire to explain, as fully as the time permits, the nature of the different undertakings included in the general scheme, and the conditions which promote or retard the particular services under administration. I have now to draw your attention to the scientific institutions existing in various parts of the country, and to the circumstances which affect their development.

2. In London we enjoy, in spite of the alleged indifference of the Government, institutions which cover a large area of science, and are supported by the bounty of the State. The British Museum, confined in its scientific character to the illustrations of natural history, has long existed a noble ornament to the metropolis. Foreign countries had, many years ago, perceived that it was necessary, for the popular apprehension of the connexion of the sciences with the industrial arts, to have supplemental museums, connecting the abstract sciences with their applications to the usual industries of the country. It was in 1835 that the necessity for such museums in England was formally brought before Government by a man of rare intelligence and singular perseverance, the late Sir Henry De La Beche. This eminent geologist was then in charge of the geological survey, which, following in the footsteps of the trigonometrical survey, lays down upon maps the geological and mineral features of the various districts, and he proposed to form a museum showing the economic uses of mineral substances.

The collections having commenced in 1835, had assumed such form in 1837 that the Government gave some rooms in Craig's Court, Charing Cross, for their reception, where they accumulated so rapidly, that first one house and then two houses became full; and finally, growing in importance and extent much beyond the

capacity of the Government houses in Craig's Court, the handsome structure in Jermyn-street, now known as the Museum of Practical Geology and Government School of Mines, was erected. The importance of giving a mining character to the institution was very obvious. The mineral produce of this country, independently of building stones and clays, exceeds the annual value of 28,000,000*l.* It was becoming, in a country so dependent on its mineral wealth, to rear a palace for the illustration of the manufactures depending upon it. The geological survey of the United Kingdom, a Mining Record Office, from which now annually comes the best statistical records of the various branches of mining industry which we possess, and the Government School of Mines, are now associated in the same building under Sir Roderick Murchison, who was appointed Director-General on the death of its illustrious founder. The votes given by Parliament during the present year for these various services are as follows:—

Geological survey of the United Kingdom - -	£8,350
Establishment in Jermyn-street, including Museum of Practical Geology, Government School of Mines, and Mining Record Office - - - -	6,198

The geological survey is simultaneously carried on in England, Ireland, and Scotland. A large portion of England and Ireland is already surveyed and mapped geologically, but the mineral survey of Scotland has been only lately commenced, because the trigonometrical survey has but recently issued the necessary maps.

With regard to the Mining School, a few remarks are necessary. England has been the last nation to found a school for the purpose of instructing those engaged in the practical pursuit of mining and the sciences bearing upon it, notwithstanding that our mining produce is about four-ninths of the produce of the whole of Europe. Now that the school is established, under professors of acknowledged eminence, the mining districts do not as yet send up that number of pupils which was anticipated on its foundation. This is certainly not owing to want of zeal or ability on the part of the professors, nor is it due to want of professional success on the part of the pupils, for most of those who have gone through

the courses are now in honourable positions. It is disheartening to the teachers that their labours are not extended over a greater area of usefulness. I believe that this will continue to be the case until a number of local mining schools are spread through the provinces. At present only two exist,—one in Bristol and another in Truro, while a third is in the act of being established at Wigan. When these extend, they are likely to become feeders to a central metropolitan school. A tree grows best from its roots upwards. The mining districts desired the establishment of a central school, but they now perceive that local schools are also necessary, and would establish them, if the activity and intelligence of the few were able to overcome the *vis inertia* of the many. I believe that the full benefit of this central school to the country will not be realized until the conditions for the erection and support of local mining schools exist. If lectures of the character now given in the Jermyn-street institution were delivered in Edinburgh, the rooms would certainly be overflowing with persons of the upper classes desirous of obtaining the benefit of courses so copiously illustrated; but mighty London cannot find more than 40 or 50 of the upper or middle classes to attend scientific prelections. Accordingly, the professors have arranged short evening courses, open only to working men living by manual labour, and these are greatly appreciated, the lecture hall for 600 persons being wholly insufficient to meet the demand for tickets.

Before leaving London it will be well to remark, that museums illustrating the industrial applications of the three kingdoms of nature now exist in it. The institution in Jermyn-street represents the uses to which mineral substances are put, while the Museum of Economic Botany at Kew, under Sir W. Hooker, shows the economic uses of vegetable substances; but, until lately, no illustrative museum was devoted to the practical appliances of animal matter. This want is being supplied by the Royal Commissioners for the Exhibition of 1851, who, starting with the co-operation of the Society of Arts, and then obtaining that of this Depart-

ment, are gradually and satisfactorily developing collections in one of the galleries of this Museum.

3. Dublin is rich in scientific institutions, chiefly supported by the State. The Royal Dublin Society was founded by Royal charter in 1749, and is supported partly by the subscriptions of its members, and partly by considerable public grants, greater, however, in former years than at the present time, when they amount to 6,000*l.* Its connexion with the Department dates from 1853. The objects of the Royal Dublin Society are carried out wholly under the responsible management of its Council, the duties of the Department in regard to them being confined to inspection and publicity, and to giving such suggestions for improvement as may occur to its officers. The Royal Dublin Society possesses a Museum of Natural History of high value; within the last few years it has been much improved in its scientific arrangements and facilities for instruction. There is also an Agricultural Museum, still imperfect in its character, but the Society is now engaged in re-organizing and placing it on a basis worthy of the successful agricultural shows of live stock and produce annually held in its premises. The library of the Society is large and catalogued, but while the admission is under rules which enable the middle classes to have ready access, its portals are not yet thrown widely open to the working classes in the evening. The Botanic Gardens at Glasnevin are well arranged, and visited freely by the working classes under liberal terms: last year 33,000 persons visited these gardens. In financial connexion with the Society, but under the responsible management of the Council of the Zoological Society, are the Zoological Gardens, aided to the extent of 500*l.* per annum by the State. These gardens on certain days have penny admissions, and in summer are open also on Sunday after hours of Divine service, and are visited by 125,000 persons annually.

The Museum of Irish Industry was founded by the Government in 1845, and was transferred from the Woods and Forests to this Department in 1853. Although corresponding in many points with the

Museum of Practical Geology, it embraces a wider field of illustration, for it includes the three kingdoms of nature—animal, vegetable, and mineral. Its name is scarcely appropriate, for while it gives prominence to the resources of Irish industry, it includes also extensive illustrations in manufactures having neither birthplace nor adoption in Ireland. The annual votes for the museum and educational courses connected with it are 4,336*l.*

The educational character of this institution is peculiar. The professors lecture during the day in short courses, chiefly attended by the upper classes of society; these courses, which are given in the premises of the Royal Dublin Society, being in fact a continuation of the system adopted by that Society before the professors were made common to both institutions. But more extended courses are also held in the evening, and are then attended by shopkeepers and working men. Examinations on the subject of each course follow, and prizes are given to the most successful students, while a general competition on all the courses attests the general progress during the year. The prizes are valued and keenly competed for, and I am glad to say that some of the most successful competitors are of the gentler sex.

There is a peculiar system in Ireland of sending lecturers in science to the provincial towns, the expenses being paid partly by the locality, but mainly by a Parliamentary vote of 500*l.* These lectures are superintended by a committee of eminent men, who arrange that examinations should be held in each town after the delivery of the course. The success of these examinations, so far as they go, has induced the Government to consider a more widely extended plan, calculated to make the permanent results greater than can be expected from the present arrangements.

4. I now pass to Scotland. While England in 1837 and Ireland in 1845 got their industrial museums, Scotland only had a promise of one in 1854, and that promise has yet to be fulfilled. During that year, Parliament, in consequence of the memorials to the Government from the chief learned bodies in Scotland,

and from the representations made by deputations of the leading men of the manufacturing and agricultural districts, agreed that the time had arrived when Edinburgh should have a museum similar to the institutions in London and Dublin. In the votes for that year the House of Commons gave 7,000*l.* for the purchase of a site upon which the museum was to be built, and Government appointed Professor George Wilson as its director, his duties being to make and organize collections, with the view of having them ready to display in the new building when completed. The site, one immediately contiguous to the Edinburgh University, was purchased, and for three years the director and his assistants have been engaged in amassing collections. These having accumulated, can no longer be properly warehoused in the temporary buildings now occupying the site, nor can they in any way be displayed to the public. Accordingly, last year the Government asked the House of Commons to vote a sum to commence the promised building. By some mistake, the project was supposed to be a new one, to which the House was not committed in principle, and so, in the then financial condition of the country, it was deemed desirable to withdraw it from consideration. This has given profound dissatisfaction to the Scotch people; but the delay obviously arose from a mistake, and not from any desire to abandon a scheme already decided upon by the votes of 1854.

In Edinburgh, in connexion with this Museum, are most valuable collections of natural history, now displayed in rooms of the University building. These came into connexion with the Department in 1854, and a remarkable result attended the increased facilities for admission then given. Formerly the charge for admission had been one shilling; it was reduced to sixpence, and one day in the week was made free. The attendance, which formerly averaged about 800 visitors, suddenly sprung up to above 100,000 annually.

The collections, both of natural history and of technology, are made available for instruction through lectures of their respective curators.

5. We have now arrived at the point at which we

have to consider the action of the Department in the promotion of provincial Schools of Science. Some preliminary subjects must, however, be alluded to before this can be understood. Government began to promote Art Schools long before it turned its attention to those for Science. The promotion of provincial Art Schools began in 1837, and in the first ten years, on a system of direct grants in aid of the schools, 23 schools were established, or at the rate of $2\frac{3}{10}$ schools per annum. When the Department of Practical Art was established in 1851, it proceeded to re-organize the system under which the Schools of Design had been aided. The grants had continually been increasing, while the local support had been decreasing. The plan adopted by the Department was to make the schools as much as possible self-supporting. The master received a sum varying in amount according to his qualifications, but not exceeding 50*l*. His chance of adequate remuneration therefore depended upon his success in teaching, the fees necessary to reward his exertions being derived from various classes of the community. Drawing is an accomplishment desired by the rich, and for which they are willing to pay. Accordingly, classes for the sons and daughters of wealthy manufacturers can be opened at high fees. But it is made a condition that when they are, classes must also be established for artisans at charges compatible with their means. The high fees of the rich render it possible to have classes at comparatively low fees for the less rich, without materially disturbing the action of a system aiming at being mainly self-supporting. Under this plan 46 Schools of Art arose between 1852 and 1856, or about 9 annually.

The system met with much opposition at first, but has now produced decided results, not only in the great increase of schools, but in the augmentation of scholars, and in the efficiency of their instruction. It was desirable to see whether the same system could be applied to the establishment of Schools of Science, which, as regards the provinces, only began in 1853, and are therefore 16 years in date behind the Schools of Art.

The conditions of the two kinds of schools were, however, clearly dissimilar. The manufacturing towns

offered no rich pupils to learn science. The sons of wealthy manufacturers very properly went to the Universities, where they could learn science better than in a provincial school, and it did not enter into the scheme of education of their daughters. The two classes, therefore, which mainly supported Schools of Art were wanting for the support of Schools of Science. The working men formed, no doubt, the most desirable constituency which they could have, but one unable by fees to render such schools self-supporting. Suppose, for instance, a case of decided success in the new establishment of a School of Science, where a hundred working men at once entered as pupils; they could not be expected to pay more than 20*s.* for their instruction, and as half of this sum, on the principle of Art Schools, goes to the committee of the school to meet local expenses, only 50*l.* would remain for the annual remuneration of the master. But while it was thus clear that Art and Science Schools could not be established upon an exactly similar basis, it would have imperilled the self-supporting system, growing so well in the case of Art Schools, if another division of the same department resorted to the old system of money grants, and adopted them without first seeing whether any less objectionable system could be devised; it was far better to win experience in the working of some provincial Schools of Science on grounds of action common to the whole Department, than to create rapidly a system of schools before practical experience was obtained as to how they would be supported. With this view, it was determined to proceed chiefly with what are known as Trade and Navigation Schools. The officers of the mercantile marine are now obliged to pass examinations under examiners in connexion with the Board of Trade, and it was desirable to establish at the outports schools in which the officers might obtain instruction in the subjects of their examination. This at once offered a constituency which could pay fees corresponding to the high fees of the upper and middle classes in Schools of Art, thus enabling us to extend the advantages of the schools to the common seamen, who could not pay high fees, and to their sons

who were about to enter upon a seafaring life. Schools of this kind have now been founded at the London Docks, Poplar, Shadwell, Liverpool, Newcastle, Sunderland, Hull, Yarmouth, Waterford, Aberdeen, Leith, and Glasgow, and could readily be established in the other outports, if we could train masters fast enough to meet the demand. I must not omit one other school, whose present locality I cannot more precisely designate, than that it is somewhere in the ocean between England and India. It is one of the finest ships of that spirited merchant, Mr. Green of Poplar, who has fitted it out as a School of Navigation, carrying a number of midshipmen under one of our masters, who is bound also to instruct the common sailors in the principles of navigation. I trust it will not be long before this noble example is followed by others, for I can conceive nothing more calculated to raise the tone and position of our mercantile marine, than to unite a thorough instruction in the science of navigation with the actual practice of seamanship as learnt afloat.

It would not be difficult to make all these Schools of Navigation amply remunerative to the master, and fully self-supporting, if we permitted him to devote his chief time to the instruction of those who are preparing to take their certificates of competency. But this would have little national result. The amount of real scientific knowledge required for Board of Trade certificates is remarkably small. A mere empirical power of computation is all that is requisite, and no scientific or intelligent understanding of the reasons of the processes is required. The seamen come for a few weeks to the schools and cram themselves in the use of logarithms and the Nautical Almanack at high pressure, blowing them off to the examiner under the same pressure, so that little remains after the operation, and then they go out again to sea. The Board of Trade had great difficulty in establishing examinations at all, and the time may not yet have arrived for their improvement, but, gradually at all events, they might be made a little more rational. There are a few honourable exceptions of mates and masters who come, voyage after voyage, to our schools, until they thoroughly

acquire a mastery of the principles engaged in their practice. As a rule, however, the officer only takes that amount of crammed instruction requisite to pass his examination, expecting the master to shovel into his brain longitudes and latitudes, logarithms, trigonometry, celestial phenomena, and the like; a large amount of fuel, but without one true spark from the torch of knowledge to set it on fire and keep it alight.

To give only this cramming would not justify the existence of Navigation Schools, and therefore each school has attached to it, as a necessary condition, a school for the preparation of boys destined for a seafaring life. This labours, however, under similar difficulties which all juvenile schools experience, that just as the boys have got over their preparatory studies, and are ready for the higher branches, their parents send them to sea. The Trinity House at Hull has successfully met this difficulty, by selecting the best 40 boys of twelve years of age, and giving them free schooling and a uniform, on condition that their parents bind them to stay for two years longer. This inducement has been entirely successful, and the school is in an admirable state of efficiency. The Trinity House at Newcastle and the Committee of the Liverpool School are about to follow this example, and it may perhaps ultimately be extended, through the zeal of shipowners, to all schools. I trust soon to see the Government offering rewards to successful boys, with the view of enabling them to stay sufficiently long to enjoy the advantages of the higher instruction.

6. In addition to the Schools of Navigation opened in the places already named, special Schools of Science, in connexion with this Department, now exist in London, Edinburgh, Dublin, Poplar, Bristol, Birmingham, Leeds, Truro, Stoke-upon-Trent, Wigan, and Aberdeen, some, in fact all, successful as to the disposition of the working classes to support them, but even those most numerously attended and increasing in numbers running the risk of abandonment at any time, because, with one or two exceptions, the expenses are greater than the receipts. I will take the case of the Potteries School of Chemistry as an illustration. It opened a year since with

numerous pupils, under a guarantee for one year of a certain amount of fees by the manufacturers of the district. The health of the master unfortunately gave way, and he had to leave suddenly. The working men of Stoke, Hanley, and Burslem apply for a new master, and register a large number of pupils. A master is sent down to make inquiries, but finds that the aggregate of their fees is only 46*l.*, and that there are no higher paying pupils in the district. He naturally refuses to accept the school at a remuneration which, including the certificate, would not amount to 100*l.* per annum, and under our present mode of action no more can be given. The meritorious desire of the working classes in the Potteries to learn the science bearing on their trade cannot be gratified. In the case of the new Mining School at Wigan, the mining proprietors have met this difficulty in advance, by subscribing a salary of 100*l.* per annum for the master, in addition to half the fees derivable from the pupils. The self-supporting system, for the reasons I have stated, is not by itself adapted to schools for the working classes, and provincial schools of science have only them to look to. Before I can point out the remedy for this evil, I must generally draw your attention to the present state of secondary education in our manufacturing districts, and of the condition of the Mechanics' Institutions which were established with the view of promoting it.

The desire of the artisan for a secondary education is not new. He has for the last quarter of a century laboured to attain it through the agency of institutions devoted to his own class, but has failed. Let us pause to reflect upon the reasons why he wants it, and why he has not succeeded in supplying his want.

7. In recent years, the most meritorious efforts have been made by the public, with the co-operation of the State, to establish primary schools; but it has been too much the practice to consider these as sufficient for the education of the people. The public have laboured zealously to bring together the materials out of which an educational edifice may in future be constructed, and have well laid some of the stones which are to consti-

tute its foundation. Milton describes a complete and liberal education to be that "which fits a man to per-"form justly, skilfully, and magnanimously all the "offices, private and public, both of peace and war." Whether the primary schools of any country, and particularly of this country, are calculated to answer the objects thus demanded of education, will be seen by a little consideration. The average period given to education by the children of the working classes, between the ages of six and fifteen, is only *three* years; after that age, labour seizes them with an iron grasp, and refuses the chance of further improvement. Now, only think of this in a practical point of view. Many of us here have sons and daughters, and would one of us dream of calling that education which they could get at any time in a period limited to three years between the ages of six and fifteen? Only about $5\frac{3}{4}$ per cent. of the whole school population of our public schools have remained more than four years, commencing from the time when they learn the elements in the lowest class. It is certain that the indifference of the working classes to avail themselves of the advantages offered to their children by the more wealthy classes, with the aid of the State, is, to some extent, to blame here, for it is found that (in round numbers) 970,000 children in England and Wales, between the ages of five and twelve, are not at school at all, their absence being unaccountable by illness, occupation, professional home instruction, or legitimate excuse of parents.

What causes this indifference? I believe the most important cause to be explained in the following passage from a recent speech by Lord Stanley: "The "school teaching of the boy has no connexion with "the after life of the man. Without a well considered "system of instruction for youths and men, the school "system, by which children only are taught, remains "imperfect and almost useless, an ample foundation, "but left without a superstructure." No doubt the early demand for labour removes many boys from school, but it has this effect because the parents do not see that the labour would have more value if the boy remained longer. The same moral feelings and kindly affection

exist in the minds of artisan parents as in our own, and they would not be slow to bestow benefits upon their children, if they had a real faith in the system which was to confer the benefit. But parents do not see how the character of continued instruction in the primary schools is to act upon the future life of the child. They aid the children to ascend the steps of knowledge, and then finding that the steps suddenly end, leading nowhere, they quickly pull them off, to prevent sudden injury by an unexpected fall. If the steps had led into an edifice where the child could have been cared for, and strengthened for his future struggle in life, depend upon it the kind-hearted parent would not have snatched him away from its portal.

8. You will now readily sympathise with the working man in his endeavours to co-operate with those who founded Mechanics' Institutions. Man in his intercourse with nature, and in his incessant struggle to compel her resources to administer to his wants, can only do so successfully through his head, not through his hands. In hands he is less potent than a monkey, which has four, while man has only two. His instincts for construction, protection, and food-supply are infinitely lower than all the animals around him. His labour consists of scientific applications of nature's laws, and is the result of intelligence, either in himself or in others: in growing civilisation, labour has less and less any characters of brute force. But in our mills and factories, if we ask how many men are employed, we are answered that there are so many *hands*. Hands, be it observed, not heads, — ambidextrous monkeys perhaps—not men made after God's own image, with a God-born desire to understand the nature of the work they are engaged in, and the reason of all they do. When the great Archetype created man, he infused into him some of the divine attributes of abstract knowledge, practical benevolence, and utilitarian power which we find employed in the creation of the universe. In the cultivation of a true science, man sees these attributes mirrored back to him. We can then readily understand why the artisan wishes (and the wish is a noble one) to attain the position of self-respect and

intellectual dignity within his reach, by understanding what he does, instead of continually turning round a dreary treadmill of labour, more dreary to him, because nature has not implanted within him strong animal instincts for work, having trusted to the intelligence of his head to supply the many necessities of his body. It is not a mere vegetative life that can satisfy the longings of a working man; as Ebenezer Elliot says, "it is more life and fuller that we want." If his daily labour only were for the purpose of supplying him with food, what better position is he in than the savages described by Livingstone in his recent work on Africa? When speaking of the electrical sparks which come from the rubbing of their fur karosses, and which have been known to them for centuries, he says, "Nothing came of it, however, for "they viewed the light as with the eyes of an ox. "The human mind has remained here as stagnant to "the present day, in reference to the physical opera- "tions of the universe, as it once did in England. "No science has been developed, and few questions "are ever discussed, except those which have an "interest in connexion with the wants of the sto- "mach." Mechanics' Institutions were on their establishment hailed with joy by the working man as a means of escape from savage ignorance, and yet they are now acknowledged failures. Whence this anomaly? There are many reasons for it, a few of which I proceed to point out.

A natural mode of communicating scientific knowledge is by the lecture system, established in remote antiquity, and pursued in our existing universities. Mechanics' Institutions of course adopted the system sanctioned by so much experience. It was natural that a lecture system should arise in ancient times. Manuscripts were rare and expensive; people who could read them were not numerous, and persons readily congregated around the more gifted to hear their own wisdom or that of others. But printing and a cheap press has altered all this. It enables mankind to get at the sources whence most instructors derive their information. If the lecturer communicate only second-hand discoveries, he

must be an able expositor indeed to render it really worth while to listen to him. Ejecting a certain quantity of known matter in the face of an audience is not education; that consists in drawing out the faculties of a man so as to enable him to apply them to the conditions of his existence. Unless the mind of the teacher actually grapples with the mind of the pupil he cannot find the dark holes in which the faculties lurk, so as to drag them to the light of day. The lecture system looks upon an audience as a mass; the school system looks upon each pupil as an individual. For instruction, I would rather leave a man with his books than take him into the lecture room, unless the lecturer understood his function as a tutor as well as a prelector. I do not mean to say that much popular information may not be conveyed through lectures to large bodies of people, but simply that they are not nearly so well adapted for the purpose of earnest education as the systematic school system. The artisans in Mechanics' Institutions soon found that they were deriving little advantage from lectures, so they gradually left, and a mixed constituency mainly rose in their support, consisting of artisans, shopkeepers, and clerks. This constituency was so mixed in its character, that discordant demands arose as to the style and subjects of the lectures, which lost their continuity and became "sporadic;" while the lecturers themselves presented a motley assemblage of professors, conjurors, ventriloquists, and musicians. This is no exaggeration, for a programme of a Mechanics' Institution is somewhat after the following fashion, the subjects which I insert as examples being those of two institutions which have asked my services as a lecturer during this year.

"Wit and Humour, with Comic Songs. Woman treated in a novel
"manner. Legerdemain and Spirit Rapping. The Devil, with Illus-
"trations. The Heavenly Bodies and the Stellar System. The Steam
"Engine. Palestine and the Holy Land. Speeches by eminent
"Friends of Education.—Interspersed with Music—to be followed by a
"Ball. Price to the whole, 2*s.* 6*d.* Refreshments in an ante-room."

Let us examine this programme philosophically, and you will find that analysis shows only two elements in it,—an element of amusement and an element of instruction. Do not ignore either the one or the other

in looking to the improvement of the artisan. We see our utilitarians alarmed at the fact, that in free libraries only half the books taken are works of solid instruction; the other half being read for relaxation and amusement. I rejoice that it is so. Why should not the working man get his lesson of morality in an agreeable manner from Thackeray, or his suggestions for public reforms in a tale by Dickens, as his arithmetic from Colenso, or his mechanics from Moseley? After his dreary unintellectual labour, why grudge him his laugh or stint in the least his enjoyment? If it be as agreeable to him as it is to myself to see the tricks of a conjuror, let him enjoy the evening on legerdemain to the full. Only separate the two elements of the programme, so that instruction and amusement are not confounded, and then mistaken one for the other; and let both be the best of their kind. My function is with the instructive section, and therefore I pass to it, but without undervaluing the desire for amusement, which the demand has shown to be a real, and common sense admits to be a natural want.

The artisan, finding the lecture system of the Mechanics' Institution did not meet his wants, seceded, and formed what has been called the Working Men's Colleges, either as separate institutions or as separate branches of the old Mechanics' Institution. Here was a great step in the right direction. This new system was founded upon the basis that systematic instruction on the school plan was essential for education; but the low fees necessary for artisan classes were insufficient to pay properly skilled teachers, and so these necessarily were volunteers, men fond of and anxious to promote education. The nature of the classes thus became an accident, the fortuitous result of particular qualifications on the part of men willing to assume the teachers' office. Reading, writing, and arithmetic were the only classes common to all. One teacher added Latin, another logic, another Greek, French, drawing, history, elocution, mechanics, &c., until some of the largest ones in England boast of having 40 to 50 classes. Now, no one who has thought of the subject would venture to depreciate the study of any of these

branches of human knowledge, or cramp the mind of any man who could take them all in with healthy draughts; but if the working man is to hover like a butterfly on the margin of one lovely flower only to be tempted away from one to another by the transient appearance of a surpassing loveliness, the variety is little likely to administer to his educational elevation. Such a system, as we find in many Working Men's Colleges, is, in my opinion, injurious to industrial instruction. It is the error in a new form of a university system engrafted upon a class not fitted for university training. It is an abstraction of education, conceived without reference to the wants of a locality, and forgetful of Pope's maxim, that we should "consult the genius of "the place in all."

The first requirement in the education of the working man is to give him his position as an intellectual being, by enabling him to understand what he is doing, that is, to explain to him the natural laws upon which his labour depends. It is not sufficient that he should be enabled to fulfil his duty; his dignity as a man requires that he should be enabled to fulfil that duty with understanding and intelligence. If public education be aimed at the first point only, all it does is to fix a handle to a tool, or a framework to a machine; the second aim ensures that the machine is the most perfect of its kind, adapted to fulfil all that is required of it. You will understand, then, that while I do not undervalue one branch of knowledge professed at these Working Men's Colleges, I think they miss the primary means of elevating the working man, because they do not concentrate their energies on a few branches of knowledge bearing on his daily life. The most successful school for working men has probably been the School of Arts in Edinburgh, founded by Mr. Leonard Horner in 1821; at all events, it can boast of a larger number of pupils and a duration of existence not possessed by any other secondary school for artisans. Its success has been mainly owing to the few subjects which it professes,—these being confined originally to mathematical science, chemistry, and natural philosophy; although, at the request of the pupils who found that they were

deficient in elementary knowledge, English, French, and drawing have since been added. The administrative duties of its Council (which I should mention consists only of gentlemen and master mechanics, not workmen) are within control, its teachers are qualified and paid, and the students have within a limited area a choice of the sciences embraced in the manufactures of their city. I have now, perhaps, said sufficient to show wherein I think the cause of failure lay, when the lecture system of the institutions gave way to a school system, founded, however, not on the limited design of a school, but on the wide comprehensiveness of a university.

9. There are some difficulties, even more fundamental than those to which I have alluded, to the speedy regeneration of Mechanics' Institutions. In the first place, the general education of the artisan in branches of primary knowledge is often so deficient as to render it impossible to convey to him successfully the objects of a secondary instruction. A great proportion of the schools now attached to Mechanics' Institutions are mere supplements to the boys' school, with the view of remedying the defects occasioned by the premature demand for labour. Until a man can read, write, and do the first four rules of arithmetic, labour in teaching him science would be thrown away. Such efforts as those of the East Lancashire Union, whose object is to promote the increase in the number and efficiency of the evening classes, whether connected with Mechanics' or other institutions, are indispensable as preliminaries to that instruction in Science and Art which it is equally the object of the Union to promote. While one does not see the way at present to make the instruction in Mechanics' Institutions wholly secondary, as it should obviously be, yet we can well conceive that if classes of science were established in connexion with them, the same gallantry and perseverance which induced the adult to go back to his school drudgery, would induce him also to go forward in the path of improvement, as soon as he attained sufficient knowledge to do so.

The next fundamental difficulty is the want of appreciation on the part of artisans, as a body, for instruction

in the science of their occupations. No doubt this exists largely, but still not to an extent so universal as is supposed; for in the schools of this Department we find men willing enough to take advantage of them, when we are able to found them on such terms of admission as working men might fairly be expected to pay. The removal of this obstacle rests mainly with the State, for its present existence is perhaps due to the fact that little or no taste for natural knowledge is given in our primary schools, supported so largely by State endowments. If some of the verbalism of schools were made to yield to the acquirement of scientific truths—if words were to give way to ideas—then the taste for science would be imbued by the boy, and a demand for its further gratification would arise when he became a man. Our primary schools have a large task assigned to them in the few years which the child of the working man devotes to instruction. The introduction of science, as a special branch of education, would therefore be attended with great difficulties. But it would be an easy thing for an apt teacher to gather round his lessons in geography much that is most attractive in the study of nature, instead of cramming the children with the names of tributaries of rivers and the names of mountains, which he is not likely to hear of again after leaving the school. Geography, thus taught, with a thorough discipline in the theory, as well as in the practice of arithmetic,—that foundation of a working man's industrial science,—would soon show their results in the increased demand for further learning, when the boy became a man.

The last and greatest difficulty of all to the establishment of secondary schools, in connexion with Mechanics' Institutions, consists in the want of adequate means; first, adequately qualified teachers; and, secondly, adequate remuneration for their services. I have already pointed out that the fees of secondary Schools of Science cannot support them to the extent which they do Schools of Art, because in the latter there is a mixture of rich and poor pupils; in the former, there are poor only. According to the present action and means placed at the disposal of the Depart-

ment, we have little power to give efficient aid. Before, however, discussing how that aid might best and most economically be given, we are met at the outset with a doubt on the minds of many, even of men of liberal intelligence, as to whether aid should be given at all to such schools, either by the State, or by the private efforts of the more wealthy in the several localities. The general argument, as presented to me, is as follows:—This country has attained a high degree of industrial prosperity, in spite of the failure of the Mechanics' Institutions and the paucity of Scientific Schools. Our Watts, Arkwrights, and Stephensons are men who have risen from low degree without the aid of such schools. Our manufacturers, as a body, do not call loudly for them. They are men of money, can pay for science, and import it when they want; and these men of money are the payers of wages to the men of sinew, and don't let us lag behind in industrial enterprise, so that our imports and exports annually increase. Though, after all, one could dismiss such a style of reasoning, as being a negation to the necessity of progress, still its prevalence demands attention. To say that because a thing is well done, therefore means cannot be found to do it better, is to mean that God's light is to be extinguished by man's darkness.

10. In this mode of opposing scientific instruction, perhaps the most common and fallacious argument is that which points to Watts and Stephensons as reasons against scientific instruction. Call such men as witnesses; hear the struggles of their life to overcome the deficiency of early education; their toilsome ascent in steps cut out, one by one, in the mountain of knowlege; and I renounce my place as an advocate, and leave the case in your hands to be decided by their evidence alone. Hear such a man as my friend and old class-mate Dr. Livingstone, the renowned African traveller, who educated himself partly by resting his book on his spinning jenny, and snatching sentence after sentence as he passed at work; but also by taking advantage of the facilities for scientific education in Glasgow, which enabled the brave-hearted young man to acquire a knowledge of science with the small

sums saved in the day from his earnings as a cotton spinner. I class among my oldest and most valued friends men now in the same social position as myself, whom I have known as cotton spinners, weavers, carpenters, and blacksmiths. Some of these men are in Scotland, and have arisen to eminence through the facilities for scientific education presented there. One or two are in England, and have learned science for themselves, and well too, without any schools to which they could have gone had they wished it. All of them, without exception, are ardent promoters of scientific instruction among the less successful class of working men. The mistake of the argument is very obvious. All the dwellers of a plain do not surmount the mountain which frowns upon them at the end of their valley. A few daring spirits have reached its summit, and passed beyond it, but the great mass of the people remain in the low-lands. It has been well said that we are not called upon to legislate for men of genius,—nature takes care of them,—but for men of mediocrity, who require aid to pass obstacles. The bold and daring man may leap from rock to rock in a foaming stream and reach the opposite shore in safety, while a man of less power and nerve would have been dashed against those very rocks which gave to the first a footing. The only way to secure a safe passage for the mass of people standing on the brink of the stream is to bridge it over, so that all may travel with little effort. The case should not be argued by contrasting natural talent and education. Education does not profess to give the gifts of God, by creating abilities in man, but merely to draw such out as are inherent within him, so that he may be enabled to apply them to his comfort and happiness in life. Schools are arenas of mental training, places for mental gymnastics, where, by systematic effort and exercise, the feeble man may become strong.

The second part of the argument alleges that our manufacturers do not demand scientific schools for artisans; many of the most intelligent certainly do make the demand, a goodly number may be indifferent to the question, but I know only one or two who meet the proposal with a frank hostility. Certainly in prac-

tice, the producers of manufactured goods are too much divided into men of money and men of sinew,—a division likely enough to be more marked as civilization progresses, unless the state gives more paternal care to the men of sinew. Formerly the hand-loom weaver made calico or cloth, but the machine took his place, or rather the places of very many hand-loom weavers; the result was that mere manipulative skill became of less importance, and manual labour, being less required, passed from the man to the boy or the girl, because their brute force or animal power was sufficient, and could be had at a cheaper rate. So the machines are constantly lowering the demand for skilled work, and are being tended by unskilled labour procured at low rates in the market—the men being set free for higher work, by a beneficent arrangement, that man may spare the sweat of his brow by the conception of his brain. As the boy and the girl answer the requirements, the man must either lower his position and work at their wages, or he must by greater intelligence rise above them, and take a part in the intellectual labour applied to production, or to the organization of the animal labour employed in it, as these cannot be undertaken by machinery. But with the mass of mediocrities in a general population, this rise in the intellectual capacity of the man will not take place unless the facilities for education are increased. What I mean is this: that as you are lessening by machinery the value of mere manipulative skill, or hand production, and making man less and less of an ambidextrous monkey, take care that you cultivate the head powers which can then be his only resource, or the last condition will be worse than the first. It is neither wise, right, just, nor generous to allow the men of money and the men of sinew to arrange this as a question between themselves; the State is the guardian of both, and is bound to devise laws for the interest of both. It is not a mere question of wages or pay. We wisely refuse to intrust the protection of our country to mere mercenaries of the sword; an almost equal danger exists in trusting to mere "mercenaries of trade." Our soldiers fight for our Queen and

country, as well as for mere pay; why should not ennobling feelings be implanted in the breasts of those who protect and advance the interests of the country by their daily labour, and are the means of advancing our civilization? Although our imports and exports are increasing, that is not a sufficient circumstance to show that the condition of our industrial development does not require attention. The faster the chariot goes, the more steady and keen-sighted should be the driver, or he will find that it jolts and jars painfully at obstacles which might have been avoided, or even runs the risk of being upset at some unexpected turn in the road. I have purposely abstained from showing you how the present state of industry is wholly dependent upon science, and that for three reasons; first, because it is a truth which will readily be admitted; secondly, because I have elsewhere treated of this subject at length; and, thirdly, because, after all, it is a low view of the duty of education. As an *argumentum ad sacchulum*, it may be politic, but it is not noble. It is a far higher and more just view for a State to take, that as the labourer is an intelligent being, made so by God to distinguish him from brutes, therefore, the State ought to enable him to infuse intelligence into his labour, and not view it as so much brute force to be bought and sold for money.

11. There is still one large class of objectors who exert great influence in preventing science from being introduced into the framework of our educational systems. They contend, that however useful science may be in promoting the utilities of life, it is neither calculated to discipline the mind (that is to strengthen common sense), nor to enlarge and ennoble the faculties. Such men, as my friend Professor Huxley has pointed out, err by scanning science as a piece of mechanism and not reading it as a poem; they are unable to rise to the generalities of philosophy, and view it therefore as a collection of dry realities, or hard facts unknit together by a common system. Perhaps this feeling has been strengthened by the observation, that science is sometimes taught as a mere accumulation of facts.

The teachers are to blame; but in all professions there may be persons without either æsthetical or philosophical capacity. Although there are men who only see pure carbonate of lime in a statue by Pheidias; who cannot see a forest because of its trees, or a town because of its houses, or a stately edifice because of its bricks,—yet it is unfair to take their view of science as a just reason for denying its power in educational development. It is no doubt true that science gives an exactness to both thought and action, which differs materially from the mode of cultivating the faculties through the graces of polite literature. We feel shocked with its prosaic character, when it tells us that diamonds are mere lumps of coal, and refuses to admit, although it admires the fancy of the poet, when he looks upon them as angel's tears, congealed as they fall on the cold and sinful world, or as drops of dew distilled from the sparkling stars. But, while science demands truthfulness as the essence of her existence, her philosophy rises also into glorious conceptions of creative wisdom. In coal, the philosopher sees, stored up for the use of man, the heat and light of the sun when it shone in ages which have long since rolled away; for when the sun shone upon the primeval forests, now entombed as coal, its heat and light passed into chemical affinity, which enabled the plants to extract their solid matters from the transparent air around them. In the combustion of the coal, the chemical affinity passes again into heat and light, so that actually, and not metaphorically, we warm and light ourselves by those solar emanations which gladdened the world some millions of years since; and in the act of doing so, we throw back into the air the carbonic acid, upon which former races of plants lived, and thus give food to the increased vegetation required by an advancing civilization. What a wonderful and bountiful benevolence is thus shown! Would not the knowledge of these beneficent provisions for the well-being of the human race, cast a new light upon the gloomy passages in which the miner works when he excavates coal for our use? It would ennoble his work and elevate his mind to feel that he was an agent to an infinitely wise benevolence,

which was providing for the well-being of the whole world. Surely the labourer would then sympathize with the feelings of Hugh Miller, the working stone-mason, when he began to understand the meaning of Saint Paul, that we are "labourers together with God."

You will find the necessity for promoting and diffusing scientific knowledge treated in an admirable chapter, by Buckle, in his recent work on the Progress of Civilization in England. He shows that, as man's moral nature remains the same in all ages, and as no new discoveries in morality take place, the changes in a civilized people must be dependent upon their relative intellectual condition, and must, therefore, result from,—1st, the amount of knowledge possessed by their ablest men; 2ndly, on the direction which that knowledge takes, that is to say, the sort of subjects to which it refers; and, 3rdly, and above all, on the extent to which that knowledge is diffused, and the freedom with which it pervades all classes of society. All this is very clear, and worthy of full thought. The practical character of a country must obviously depend not only on the amassing of knowledge by its philosophers, but also upon its diffusion among the people. It is not a knowledge merely of natural laws which makes a people wealthy; it is the power of applying them to the every-day purposes of life, that produces riches. Philosophers very rightly remain with their abstractions, as a fountain remains at its source, or trickles away from its fulness in a narrow stream. If you wish to make that fountain useful to the surrounding country, you construct a reservoir for its waters, and channels by which to conduct them to the fields requiring irrigation.

12. I now trust you will admit, with me, the several points to which I have directed your attention, at least to this extent, that Mechanics' Institutions, as schools for the working classes, have not fully realized their objects, and that, with the unaided efforts of the working classes it was impossible they could do so. Next, that it is reasonable, just, and politic for the public, either through the agency of the Government, or by local or benevolent effort of the wealthy, to give

the conditions for success to systematic secondary schools for the instruction of working men.

In aiding schools of secondary education, there are two obvious methods of procedure:—(1.) We may aid them to accomplish what they desire; (2.) We may reward them for its accomplishment. Both of these plans have advantages. There does not yet exist a staff of well-educated teachers to take charge of the classes of a secondary school, and it may be the duty of the State to aid in their development. All that we are doing in that direction in the Department, as regards scientific schools, is purely limited to an experiment, and does not partake of a national character. As servants of the public, we have no right to create large national systems of aid, until they have been fully considered and sanctioned by Parliament; and then the State should only do what is left undone by the unaided efforts of the public. We have done our best to establish schools on the system now sanctioned, viz., that of self-support, and we find that it is not adapted to secondary schools of science having only a constituency of working classes to support them. The few teachers who are in training are therefore taught merely as a means of experimentally trying a better system on a small scale. Of course there are other methods, besides the training of teachers, by which means could be provided to promote the establishment of scientific schools, though as much as possible should be left to local effort and management. The second principle of aid, by rewarding the teacher for what he has achieved, and the pupil for the knowledge which he has attained, is, on the whole, a more wholesome system than the other, and less liable to abuse in its administration. On this principle, the State wishing its working classes, for instance, to know so much chemistry and so much mechanics, because they are essential to the welfare of the nation, would say,—we consider that a given amount of such knowledge is worth so much, and we will reward you, the teacher, who communicates it, or you, the learner, who learns it. Such a system founded on examination, carefully guarded, is obviously the one in which the

people are willing to co-operate, as evidenced by recent experiments on a large scale by the Society of Arts, the Hants and Wilts and the East Lancashire Unions. It leaves the public to find out their own teacher and their own means of study, without creating a large body of masters spread over the country, more or less in the pay of the State, and therefore looked upon with more or less suspicion. Clearly at the beginning of a new national movement for the regeneration of Mechanics' Institutions, you must give both kinds of aid; that is, you must aid in the means for accomplishing, and also reward the accomplishment. But gradually, the first plan should dwarf, and the second plan increase its proportions.

13. Throwing open the civil service of the Crown to competition is an illustration of what the public desire as aids to their education. If all the public offices in the State, except the staff ones, were thrown open to competitive examination, an undoubtedly great influence on the education of the country would be exerted. But whether that influence would ultimately be good or bad must depend upon the kind of knowledge for which the rewards of State employment are offered. I will illustrate my meaning by reference to results experienced in Germany not many years since. The German States, towards the end of the last century and the first part of the present one, fully perceived the necessity of educating their population, and schools were liberally spread over the country, both for the poor and for the middle classes. Classical education, which operates on the truth that man's moral nature is always the same, and that therefore the human passions may be governed by a knowledge of past experience, was made the groundwork upon which the German schools were taught. The schools succeeded admirably, and their pupils were worthy of the excellent instruction which they received. But, after being educated, they naturally looked for employment in the direction of their education. They said to the Government which had established those schools—you have taught us how to understand the nature of our fellow-men by the experience of the past, we can now aid you to govern them;

give us employment. It was in vain for the Government to say, we have given you a good education; go and work for yourselves. The natural answer was—the sort of education which you have given does not at all adapt us for an industrial life. We know much about history, logic, and philosophy, but nothing about manufactures and commerce. Accordingly, the Government had gradually to enlarge their bureaux for the reception of their well-educated men, until finally, one in sixty of the population entered into State employment. Then the Trade or Industrial Schools were opened, which, giving an education in the direction of production, drew off men's minds from looking to the State as the only source of respectable employment, relieving the old pressure, while it increased the resources of the country.

I think there is a lesson in this experience which we would be well to learn in time. I agree to the full, that entrance should be had to State service by open and unreserved competition. But if this principle be admitted, the public should look with extreme jealousy on the nature of the examinations to which the candidates are to be subjected. The amount of State employment in this country is very small in proportion to the amount of private employment. The throwing open public offices to competition necessarily implies that many more persons will compete than can be successful. Now, if the examination be purely abstract in its character, and be directed only to Government requirements, the result must follow that you have stimulated many unsuccessful persons to acquire an education which is not the least, nay more, which is probably the worst, adapted for the private employments upon which they must now fall back. The stimulus thus given to education would be of the most unhealthy kind, and would soon give a triumph to those who desire to keep to the present system of Government patronage. It is not a sufficient reply to say, that there are certain things in the competition common both to Government and private employment, such as arithmetic, spelling, and writing. My conviction is, that it would be a small result

to the country, if offices were given for success in primary education. Competitive examination for State employment should either promote secondary education as the means for admission, or the system had better remain as it is at present,—examination on nomination. Reading and writing, spelling and arithmetic should be the *sine qua non* qualifications for admission to the ranks of the candidates who are to compete for State employment. The preliminary conditions might be ascertained by another set of examiners, such as the inspectors of schools, and their certificates be rendered necessary to enable the candidate to present himself as a competitor for State employment. As it is the secondary education of this country which is in such a backward state, all the weight of a State should be thrown into its development, under regulations which would make the acquisition of primary instruction a matter of necessity—its absence a scandal, not its mere presence a subject for State reward. Then, as regards the secondary examinations for State employment, it would be better rather to direct them towards industrial subjects, than to distract the attention of the people from them to the more limited objects of official employment. The man who has engrafted secondary instruction on his primary knowledge, will soon bring his intelligence to bear on the subordinate situations of a Government office, and acquire its specialties during his probation. In this country private employment is ranked as honourable as State service, and I do not wish to see the system of open competition for the latter either lower the former or lessen the fitness of the mass of unsuccessful candidates to fall back upon the productive industry of the country for employment; but I do foresee great danger in this direction, unless the public most jealously watches the system of examinations adopted.

I have now endeavoured to point out to you some of the difficulties which have attended, and which must for some time continue to attend the diffusion of scientific knowledge throughout the country. Very many earnest men are now engaged in devising schemes for the promotion of primary instruction, and some few men, like Lord Brougham and Lord Stanley, in laying

the foundation for efficient secondary instruction, feeling convinced that the alphabet of knowledge, though a means of reaching it, is not knowledge itself. Primary and secondary instruction combined may be entitled to the term education, but certainly neither by itself has any right to usurp the word. It is not enough to sow the seed; if we wish a plant to be full in ear and rich in grain, not only must it be tended when it first bursts forth from the ground, but the sun must shine and the rain fall during all its growth, until the plant grows to the fulness of maturity, and yields its abundant harvest for the support and comfort of man.

There is not an intelligent person in this country who does not most earnestly wish to support education, but we cannot agree upon a system that will not rub against some of our own miserable prejudices which we worship with an idol-fondness. Many wish the artisan to learn nothing but the elements of learning. Others preach art as the means of ameliorating his condition, and a few see his regeneration in the diffusion of scientific knowledge. All our educational controversies are much open to the censure which Baron Liebig has given in relation to one branch of learning:—

"There are building materials in abundance, so as "almost to cover the ground on which the edifice should "stand; but the master builders are quarrelling, and "their minds are not made up as to the plan. One "would have the structure of wood; another thinks "it ought to be of stone and wood; a third, that it "should consist only of stone and iron. Two of these "materials should at all events be employed; but all "three, if properly combined, would yield an excellent "building, were it not for the labourers, who will have "it made up of straw, and built in the air. It is "because of that, even the foundation is not finished."

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